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EXPERIMENTS ON THE STRENGTH OF WROUGHT-IRON STRUTS.

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The following experiments were made at the Pencoyd Iron Works, Pencoyd, Pa., for the purpose of determining the comparative resistance to compression of long and short struts of rolled angle, tee, beam and channel sections. The specimens were tested by four different methods:

First, with flat ends, between parallel plates, to which the specimen was in no way connected.

Second, with fixed ends, or ends rigidly clamped to parallel plates, the plates substantially forming flanges to the specimen under test.

Third, hinged-ended, or both ends fitted to hemispherical balls and sockets, or cylindrical pins.

Fourth, round-ended, or both ends fitted to balls resting on flat plates.

NOTE.—The discussion on this paper will be published subsequently.

The machine used was a Fairbanks testing machine of 50 000 pounds capacity. In this machine the power was applied by hand through a system of gearing to four vertical screws, which connected two rigidly parallel plates, between which the specimen was placed in a vertical position. The pressure applied was measured on an ordinary scale-beam, pivoted on knife edges and carrying a moving weight, which registered the pressure automatically. The specimens varied in length from 6 inches up to 16 feet, and were selected to obtain a uniform character of material. As far as possible, the long and short specimens of the same size were cut from the same bar.

These test bars were all accurately straightened, dressed square on the ends, and weighed; the area of cross section being determined by the weight and length of the bar. The hinged-ended and round-ended specimens were arranged so that the centres of balls or pins were, as near as practicable, coincident with the centre of gravity of the cross section of the bar. Every known precaution was observed in order to obtain accurate results, and the disparity in these results seems to be due to unavoidable inequalities in the condition of the bars, as hereafter noted. Very minute changes in the position of the centre of pressure produced greater differences in the resistance of the bars than was anticipated.

Judging from previous experience, the result of any few indiscriminate tests would yield no satisfactory conclusions; it was, therefore, determined to make such a number of tests that the range of maximum and minimum could be fairly established, and a proper average deduced therefrom. For reasons not always evident, occasional results were obtained either abnormally high or low, as will be found illustrated on the diagrams; but there is little doubt that the principal cause of low resistance was eccentricity of axes, or non-coincidence between the centre of pressure and the axis of greatest resistance of the specimen.

This was most evident on hinged-end struts of a symmetrical cross section, such as I beams and welded tubes, with which it was occasionally found that the highest resistance was not always obtained when the centres of balls or pins were placed in exact line with the centres of the section, as described on the ends of the bar. Sometimes, by moving the specimen apparently slightly out of centre, the resistance was vastly increased. This was, no doubt, due to minute bends or inequalities in the distribution of the metal, which caused the axis of greatest resist-

ance of the strut to disagree with the apparent axis of symmetry. A few examples of this character are described in the tables.

When the bar was straight and accurately centred on the ball or pin, the hinged-ended strut of any length was fully equal to that of the flat-ended.

In fact, the resistance of the best specimens of hinged-ended bars exceeded the best of the flat-ended. This behavior, as illustrated on the diagrams, occurred in so many instances that it could not be considered exceptional, but the slightest deviation from the requisite accuracy of centring rapidly reduced the resistance; and as no amount of care could always insure the precise conditions required, it is not believed that in practice, with the most careful workmanship, or the best form of strut or column, could these high resistances be uniformly obtained.

When the bars were very long, in proportion to radius of gyration, the ultimate load could be applied without any permanent injury to the bar. The strain could thus be released and applied at will without any change in resistance. Several bars were tested in this manner, and the effect of change in end conditions noted, a few examples of which will be found in the tables.

The high resistance on balls or pins could always be obtained by trial, that is, by observing the direction of deflection under strain, then releasing the strain and moving the bar in the proper direction; when the point of greatest resistance was passed, the deflection would be reversed in direction.

When the point of greatest strength was reached, the behavior of the specimen was peculiar. Under ordinary circumstances the bar, while bending under strain, rotated from the start on its hinged ends. When correctly centred, no such rotation occurred at the beginning of deflection, but the bar bent, like a flat-ended strut, until the point of failure was reached, when it rotated on its ends suddenly, and with so much force as sometimes to spring from the machine. In fact, the deflection under these conditions more resembled that of fixed-ended than of flat-ended specimens, for the latter frequently showed indications of rotation on their ends before ultimate resistance was attained.

In no instance could the effect described be produced on a round-ended strut, and the smaller the pin or ball and socket the more rarely it occurred, or the more difficult to produce it by trial, just as an egg may be stood erect in a very minute cup, but never on a flat table. The

diameter of the ball or pin exercised a marked influence on the resistance of the bar, as also did the fit of the pin. A few examples are given in the tables illustrating the effect of a change in pin diameter. The test, No. 125, of a hinged-end angle was made on new pins, which were an absolute fit to the semi-cylindrical seat which capped the specimen, the test being made with the pin hinges dry.

The caps were immediately eased with a file and the bearing on pins lubricated, when it was found impossible in the same bar to reproduce the high resistance first obtained. The hinged-ended tests varied all the way from the value of round-ended up to flat-ended. As can be seen on the diagrams, the lowest range of hinged-ended tests approximated very closely to the average of round-ended.

The ends of the shortest flat-ended struts remained solidly seated at the time of failure, whilst, on the contrary, the longest struts always rotated on their ends, and, as stated before, sometimes showed a tendency to turn before ultimate resistance was attained.

In all cases the bars bent in the direction of the least radius of gyration, excepting a few special tests of T sections, when the specimen was designedly placed eccentric on the hinge, causing failure in the direction of the stem instead of the flange; and also excepting the case of very short specimens, which failed by direct crushing.

During some tests, the particulars of which are given hereafter, the deflection of the bars apparently reversed as the load increased. This was due to the occasional deflection of the specimen in the form of a sinuous reverse curve, which always merged into a regular curve before failure.

But sometimes the greatest curve unexpectedly reversed, the least curve finally predominating. Bars, deflecting in this manner, usually exhibited unduly high resistance.

This action, it seems, occurred more frequently with flat-ended than with hinged-ended specimens. For the purpose of observing the effects of cold straightening, on bent bars, a number of bars were straightened in the rolling machine, after the first test, and then retested. When the bars were long as compared with section, and the permanent bend slight, no diminution of strength was noticeable, but in the case of shorter bars, in which the distortion was more serious, a weakening approximating 10 per cent. was found.

The shortest lengths of fixed-ended angles show lower resistance

than either the flat-ended or hinged-ended. As the length of the fixed-ended struts was measured between the clamps, whereas the point of absolute fixing probably occurred at some place within the clamps, the apparent difference may be accounted for, as then the values given for $\frac{l}{r}$ would be too low. Also the shortest bars of channel section offered less resistance than tees or angles, as compared by equal radii of gyration. These channels were tested at Watertown, as recorded elsewhere, but the difference may be accounted for by reason of the greater extent of unbraced web surface in the channels, rather than by supposing that the machines at Watertown and at Pencoyd would yield such discordant results. The channels showed local failure, or crippling rather than bending, when $\frac{l}{r}$ was as high as 37, whereas, with angles and tees, no such local failure was observed when $\frac{l}{r}$ was higher than 30. The tests of welded tubes show fully as much diversity in results as the other shapes. The seeming contradictions in the tubes were partly due to their usual lack of uniformity in thickness, being thickest on the line of the weld, and liable to have thin spots anywhere. In one test a hinged-ended tube offered higher resistance when placed slightly eccentric, or apparently so, on the ball end. The 2½ inch tube 8 feet long recorded in test No. 271 failed flat-ended with a pressure of 33 020 pounds. It was then straightened and retested in the same manner, failing with 31 000 pounds. As this seemed too feeble a resistance, another tube was taken, test No. 270, which did not fail, flat-ended, with 50 000 pounds, but placed on 2-inch balls and sockets, test No. 294, it failed with 43 990 pounds. For the behavior of some other tubes, see table of continuous tests.

Lateral Deflection of Struts during Compression.

For obtaining the deflection, a straight-edge of the same length as the specimen was used.

The extent of deflection was measured by a wedge-shaped gauge, tapering one to ten. Each one-tenth of an inch advance in length, advanced one-hundredth of an inch in width.

The specimen was first subjected to a moderate pressure in the machine, varying from 100 to 500 pounds, according to the size of the bar, and the amount of its curvature, if any, then measured. Although the bars were considered straight in a practical sense, yet refined measurement generally showed some appreciable curvature.

Thus the first measurements, recorded in the left-hand columns of each table of deflections, indicate the initial curvature of the bar. In the second columns, on right-hand side of the tables, the total pressure that the bar sustained is given, and in the extreme right-hand columns is given the amount of permanent deflection remaining in the bars after the pressure was released. On many bars the pressure was released at intervals during the test, to ascertain if any permanent deflection remained, but none was observed until the bar had either attained ultimate resistance, or was on the verge of failure.

It will be noticed that in many instances failure occurred with some even multiple of 100 or 1 000 pounds. This was generally due to failure occurring during an interval when the machine was stopped to measure the deflection. In many cases the operator ceased increasing the pressure when indications of failure were evident. These indications in bars of moderate length consisted of the dropping of scales from the specimen, or a rapid increase of the deflection.

In most instances the ultimate resistance might have been either slightly increased or diminished if the application of pressure had been correspondingly continued or retarded, but the variation from the recorded pressures would not have seriously affected the result. The hinged tee No. 147 sustained a pressure of 50 000 pounds about four minutes before failure occurred.

The fixed-ended angle No. 181 showed partial failure, but not entire, although the load remained on for several minutes. Similar action was developed in specimens Nos. 242, 87, 72.

In some cases the amount of deflection was reduced as the pressure increased, which was due to the direction of greatest deflection being reversed under strain. This occurred in thirteen tests with flat-ended bars, in four tests with hinged bars, and in no instance with round or fixed-ended.

There was a certain range of length of the specimens below which all bars took a permanent set after failure, and above which all recovered their original condition. In the flat-ended bars recovery occurred

when the ratio of length to least radius of gyration $\left(\frac{l}{r}\right)$ was as low as 231, and one test showed permanent set with $\frac{l}{r}$ as high as 370. Between these limits some specimens recovered, others did not. All specimens below 231 were bent; all above 370 recovered. In hinged-ended bars the range was from 162 to 254. In fixed-ended bars a similar range of $\frac{l}{r}$ extended from 174 to 312. In round-ended three tests occurred without permanent set after failure; in these $\frac{l}{r}$ ranged from 439 to 449.

It has been previously stated that when $\frac{l}{r}$ was about 30 the bars ceased to bend in a regular curve, but failed by irregular crippling. It is probable that this limit would be found to vary for the different classes of end connections, but as the limited capacity of the testing machines necessitated the use of very small sections, of such short lengths, to operate upon, the subject could not be satisfactorily determined.

Methods of Securing Ends of Struts.

Plate XXV, Figure 1 represents the ball and socket, Figure 2 the pin, and Figure 3 the clamps for fixed-ended angles.

For round ends the socket was omitted, the ball resting against a flat plate. The studs *A A*, shown on Figures 1 and 2, were fitted into holes in the hinge plates, which were drilled directly in line with centres of ball or pin. These studs were used only with angle and tube sections, their diameter being regulated so as to bring the centre of gravity of the angle section in line with the centre of ball or pin. A number of these studs was provided having slightly varying diameters, by means of which the angle could be moved as desired on its hinged ends.

For the other sections, the studs *A A* were omitted. The struts had lines described on their ends at right angles to each other, and passing through the centre of gravity of the section.

The ball and pin plates had also diametral lines, at right angles to each other, as shown on drawing.

The lines on the struts and on the plates were made to coincide, which was readily done by means of a light mallet, as soon as the bar was pinched in the machine.

Concentric lines, as shown, were described on the hinge-plates, which were convenient to measure from when adjusting.

The length of the strut was taken as indicated by letter l, which will account for the different tabulated lengths of the same bar, when tested with different end fixtures. Some tests made on very short bars $\left(\frac{l}{r}\ 30 \text{ or under}\right)$ showed an irregularity, owing to the length of the hinge-caps being added to the actual length of the specimen, when determining the values of $\frac{l}{r}$, as the specimens then failed partially by crushing, and the method of securing the ends made little, if any, difference in the results.

A few tests thus made were rejected as untrustworthy, and the tests Nos. 112, 113, 114 of angles, and 162, 163, 164 of tees, were made on bars whose ends were milled to fit directly on the pins, and the lengths of the specimens taken between the inside faces of the pins.

During the round-ended tests the abutting ends of the balls became slightly flattened by the repeated pressures. This flattening became more marked towards the close of the experiments, giving the balls a certain area of flat bearing and probably causing some increase of the proportionate resistance. As this action could have been prevented only by the use of balls and plates of hardened steel, and would be expected if round-ended struts were used in practice, it was considered best to retain the iron balls.

The balls and pins were moistened with oil to reduce the friction during hinged-end tests.

TABLES OF RESULTS.

For convenience of reference, the tests are numbered on the tables, and correspondingly numbered on the diagrams. The unnumbered tests on Diagram No. 7 were made on the Government machine at Watertown; the particulars of these are given in Table No. 7. The expression $\frac{l}{r}$ means the length of strut divided by least radius of gyration, the latter being derived from the moment of inertia of the respective cross-sections, taken around an axis passing through the centre of gravity of the section, in the position described below:

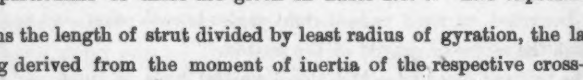

PLATE XXV
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Fig. 1. Ball and Socket.

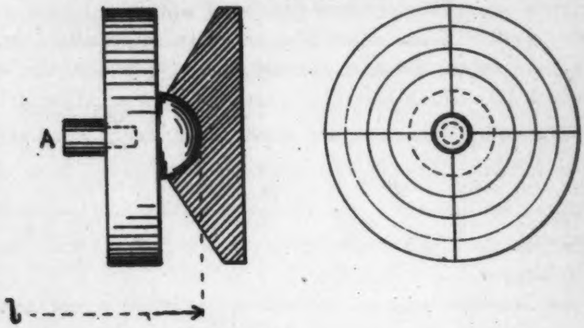


Fig. 2 Pin.

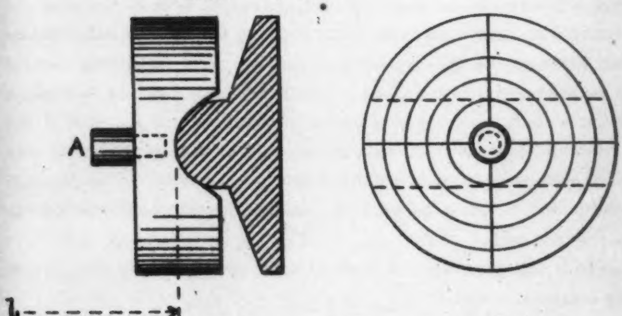
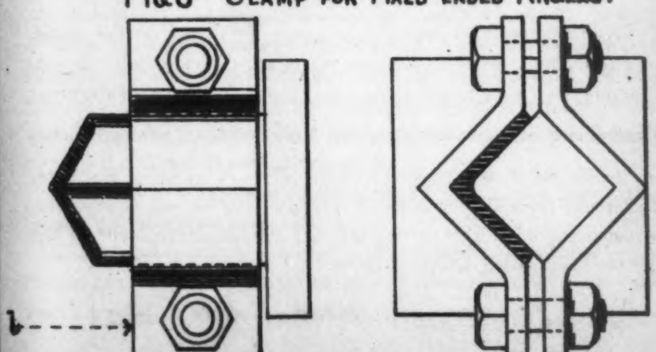


Fig. 3 Clamp for Fixed ended Angles.



½ Size.

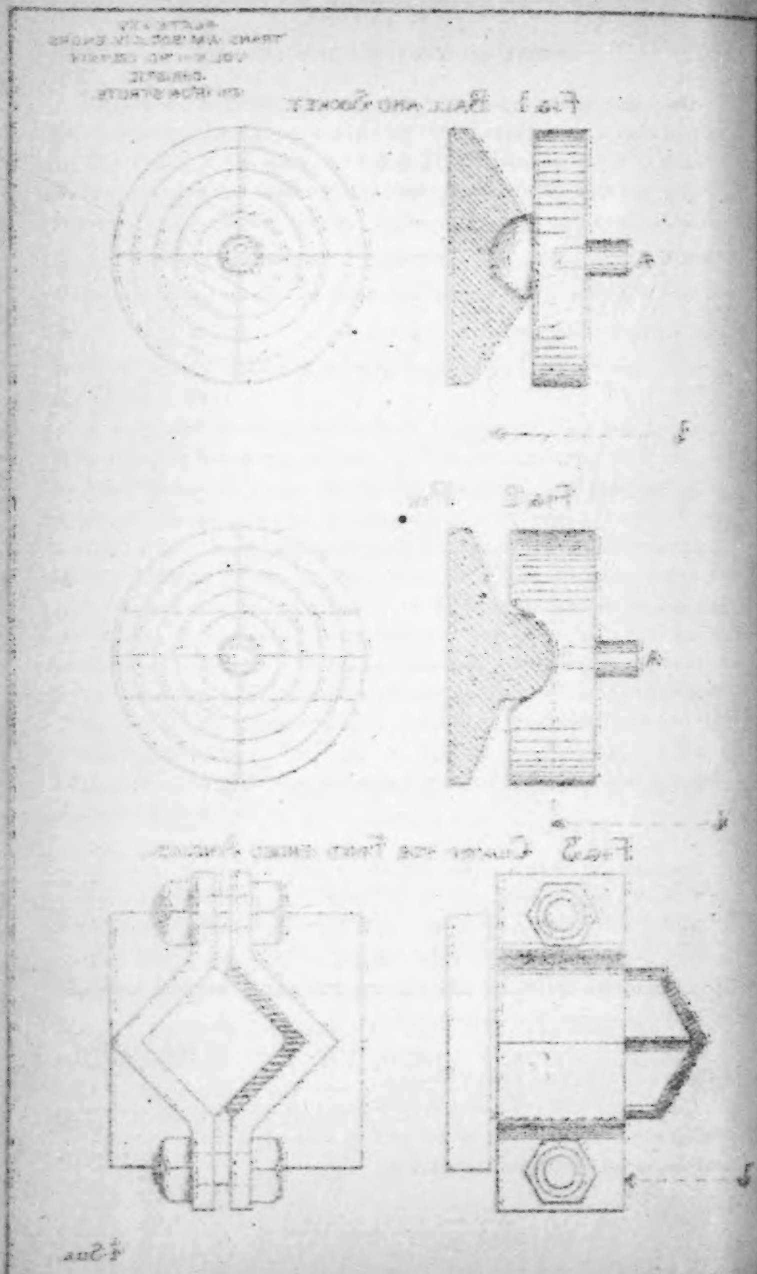


Fig. 1. Ball and Socket.
Fig. 2. Pin.

The value of the least radius of gyration for the sections experimented upon is as follows:

r = value of least radius of gyration in inches.

Angles.	r.	Tees.	r.	Beams.	r.	Channels.	r.	Tubes.	r.
$1 \times 1 \times \frac{1}{8}$	.20	1×1	.26	4″	.51	2″	.31	1″	.43
$1\frac{1}{4} \times 1\frac{1}{4} \times \frac{1}{4}$	.26	$1\frac{1}{4} \times 1\frac{1}{4}$	.27	5″	.60	3″	.46	$1\frac{1}{2}$″	.61
$1\frac{1}{2} \times 1\frac{1}{2} \times \frac{1}{4}$	.31	$1\frac{1}{2} \times 1\frac{1}{2}$	.32	6″	.66	4″	.48	2″	.77
$1\frac{3}{4} \times 1\frac{3}{4} \times \frac{1}{4}$	.36	2×2	.43	....	....	5″	.45 to .56	$2\frac{1}{2}$″	.94
$2 \times 2 \times \frac{5}{16}$	.40	$2\frac{1}{4} \times 2\frac{1}{4}$	.55	....	....	....	....	3″	1.17
$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$	.50	3×3	.62	....	....	6″	.51 to .67		
$2\frac{3}{4} \times 2\frac{3}{4} \times \frac{3}{8}$	.55	$3\frac{1}{2} \times 3\frac{1}{2}$	.74						
$3 \times 3 \times \frac{3}{8}$	.60	4×4	.84	....	....	8″	.60 to .71		
$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{3}{8}$	.70								
$4 \times 4 \times \frac{3}{8}$	.81	....	....	....	....	10″	.69		
$4 \times 3 \times \frac{1}{2}$	.66	....	....	....	....	12″	.87		

The tables of deflections have been previously explained.

Table No. 9 is an average for the ultimate resistance per square inch of section for each shape of struts. The figures agree with the dotted lines on the diagrams, which were obtained by describing curves corresponding to the maximum and minimum range of tests, and locating midway the curves of average resistance.

Table No. 10 is a general combined average of all the tests, without reference to any particular sections.

These latter tables are given only as tentative, and probably approximating to a correct result, which may be determined by more careful analysis, aided by further experiments.

COMPRESSION TESTS.

Flat-ended Angles.—No. 1.

No.	Shape.	Size.	Length.		Area.	Ultimate Lbs. per Sq. Inch.	$\frac{l}{r}$	Remarks.
		In Inches.	*Ft.*	*In.*	*Sq. In.*			
1	Angles.	3 x 3 x $\frac{3}{8}$	8	0$\frac{3}{32}$	2.09	19 569	158	
2	"	2$\frac{1}{2}$ x 2$\frac{1}{2}$ x $\frac{3}{8}$	8	0$\frac{1}{8}$	1.76	18 466	188	
3	"	2 x 2 x $\frac{5}{16}$	8	0$\frac{1}{4}$	1.07	13 738	235	
4	"	1$\frac{1}{4}$ x 1$\frac{1}{4}$ x $\frac{1}{4}$	8	0$\frac{1}{4}$	.57	5 185	356	
5	"	1 x 1 x $\frac{1}{8}$	8	0$\frac{1}{4}$	.24	1 955	481	
6	"	3 x 3 x $\frac{11}{32}$	6	6$\frac{1}{8}$	2.10	22 476	128	
7	"	2$\frac{1}{2}$ x 2$\frac{1}{2}$ x $\frac{3}{8}$	6	6$\frac{1}{4}$	1.76	20 909	153	
8	"	2 x 2 x $\frac{5}{16}$	6	6$\frac{1}{4}$	1.15	20 013	191	
9	"	1 x 1 x $\frac{1}{8}$	6	6$\frac{3}{8}$	.23	2 564	392	
10	"	2$\frac{1}{2}$ x 2$\frac{1}{2}$ x $\frac{3}{8}$	5	0$\frac{3}{16}$	1.74	26 437	118	
11	"	2 x 2 x $\frac{5}{16}$	5	0$\frac{1}{4}$	1.15	21 478	147	
12	"	1 x 1 x $\frac{1}{8}$	5	0	.23	6 838	300	
13	"	2 x 2 x $\frac{5}{16}$	3	6$\frac{1}{8}$	1.14	24 123	103	
14	"	1 x 1 x $\frac{1}{8}$	3	6$\frac{1}{8}$	.23	16 883	211	
15	"	2$\frac{1}{2}$ x 2$\frac{1}{2}$ x $\frac{3}{8}$	3	6$\frac{3}{8}$	1.76	27 841	83	
16	"	2 x 2 x $\frac{5}{16}$	3	6$\frac{1}{8}$	1.14	28 500	103	
17	"	2 x 2 x $\frac{5}{16}$	2	0	1.15	29 217	59	
18	"	1 x 1 x $\frac{1}{8}$	2	0$\frac{1}{8}$	.24	31 799	121	
19	"	1$\frac{1}{2}$ x 1$\frac{1}{2}$ x $\frac{1}{4}$	1	6	.67	37 910	58	
20	"	1$\frac{1}{2}$ x 1$\frac{1}{2}$ x $\frac{1}{4}$	1	6	.67	32 089	58	
21	"	1 x 1 x $\frac{1}{8}$	1	6	.24	33 330	90	
22	"	1$\frac{1}{2}$ x 1$\frac{1}{2}$ x $\frac{1}{4}$	1	0$\frac{1}{16}$	.70	38 944	39	
23	"	1 x 1 x $\frac{1}{8}$	1	0$\frac{1}{8}$	.24	38 818	61	
24	"	1$\frac{1}{2}$ x 1$\frac{1}{2}$ x $\frac{1}{4}$	0	6	.66	53 030	19	
25	"	1 x 1 x $\frac{1}{8}$	..	5$\frac{15}{16}$	.27	43 773	30	
26	"	1 x 1 x $\frac{1}{8}$	..	6$\frac{1}{8}$	.23	39 780	30	
27	"	1$\frac{1}{4}$ x 1$\frac{1}{4}$ x $\frac{1}{4}$	..	6$\frac{1}{8}$	.56	51 400	23	
28	"	1$\frac{1}{2}$ x 1$\frac{1}{2}$ x $\frac{1}{4}$	..	6$\frac{5}{16}$	.66	46 440	20	
29	"	3$\frac{1}{2}$ x 3$\frac{1}{2}$ x $\frac{3}{8}$	10	6$\frac{1}{4}$	2.42	16 290	183	
30	"	2$\frac{3}{4}$ x 2$\frac{3}{4}$ x $\frac{3}{8}$	10	6$\frac{1}{4}$	1.93	11 530	225	
31	"	4 x 3 x $\frac{15}{32}$	15	5$\frac{3}{8}$	3.06	7 380	285	
32	"	4 x 4 x $\frac{3}{8}$	15	0$\frac{1}{2}$	2.83	8 240	229	
33	"	3 x 3 x $\frac{7}{16}$	15	0$\frac{1}{4}$	2.47	6 210	322	
34	"	4 x 4 x $\frac{3}{8}$	15	0$\frac{5}{16}$	2.96	12 400	228	
35	"	2$\frac{1}{2}$ x 2$\frac{1}{2}$ x $\frac{3}{8}$	15	0$\frac{3}{8}$	1.72	4 490	353	Same bar as No. 192.
36	"	2 x 2 x $\frac{5}{16}$	15	0$\frac{1}{8}$	1.12	2 590	439	Same bar as No. 194.
37	"	2 x 2 x $\frac{5}{16}$	6	6$\frac{1}{4}$	1.15	20 000	191	
310	"	2 x 2 x $\frac{1}{4}$	2	0	.92	36 560	60	
311	"	1$\frac{3}{4}$ x 1$\frac{3}{4}$ x $\frac{3}{8}$	2	0	1.03	32 810	68	
312	"	2 x 2 x $\frac{1}{4}$	1	6	.92	33 140	45	
313	"	2 x 2 x $\frac{1}{4}$	1	0	.92	35 900	30	
314	"	2 x 2 x $\frac{1}{4}$	..	6$\frac{1}{8}$	.92	44 000	15	

LATERAL DEFLECTIONS OF FLAT-ENDED ANGLES.

THE UPPER FIGURES REPRESENT PRESSURES IN POUNDS.
THE FIGURES BELOW ARE THE CORRESPONDING DEFLECTIONS IN INCHES.

Number.										Ultimate Pressure.	Permanent Deflection.
1	1 000	3 000	6 000	9 000	12 000	15 009	20 000	30 000	40 000	40 900	1.40
	.03	.06	.08	.10	.12	.12	.12	.15	.37		
2	1 000	4 000	8 000	12 000	16 000	20 000	24 000	28 000	32 000	32 500	1.00
	.04	.08	.12	.18	.22	.24	.30	.37	.56		
3	1 000	2 000	4 000	6 000	8 000	10 000	12 000	14 000	......	14 700	.34
	.03	.03	.06	.06	.06	.09	.19	.38	......		
4	100	200	600	1 000	1 400	1 800	2 200	2 600	2 800	2 950	.06
	.00	.05	.07	.08	.09	.10	.15	.17	.22		
5	100	200	300	400	......	......	......	......	......	475	.00
	.10	.12	.18	.28	......	......	......	......	......		
6	500	5 000	10 000	15 000	20 000	25 000	30 000	40 000	45 000	47 200	.77
	.07	.11	.14	.12	.11	.11	.12	.15	.19		
7	1 000	4 000	8 000	12 000	16 000	20 000	24 000	30 000	35 000	36 800	.37
	.09	.13	.16	.18	.19	.19	.21	.24	.31		
8	500	3 000	6 000	9 000	12 000	15 000	18 000	......	......	18 500	.58
	.05	.12	.14	.14	.14	.16	.33	......	......		
9	100	200	300	400	500	......	......	......	......	600	.00
	.04	.04	.05	.05	08	......	......	......	......		
10	500	3 000	5 000	10 000	15 000	25 000	35 000	40 000	45 000	46 050	.70
	.03	.06	.09	.10	.10	.11	.12	.14	.25		
11	500	3 000	6 000	9 000	12 000	15 000	18 000	21 000	24 000	24 700	.81
	.02	.03	.02	.06	.10	.12	.14	.18	.32		
12	100	300	500	700	900	1 100	1 300	1 500	......	1 600	.00
	.06	.14	.17	.22	.23	.26	.30	.40	......		
13	500	5 000	10 000	15 000	20 000	25 000	......	......	......	27 500	.45
	.00	.00	.01	.02	.05	.15	......	......	......		
14	100	400	800	1 200	1 600	2 000	2 600	3 200	3 800	3 900	.15
	.03	.04	.04	.04	.03	.03	.05	.08	.26		
15	5 000	10 000	15 000	20 000	25 000	30 000	35 000	40 000	45 000	49 000	.23
	.00	.02	.03	.03	.03	.03	.04	.04	.05		
16	500	5 000	10 000	15 000	20 000	25 000	30 000	......	......	32 500	.92
	.04	.05	.08	.10	.12	.14	.17	......	......		
17	500	5 000	10 000	15 000	20 000	25 000	30 000	......	......	33 600	.28
	.01	.01	.02	.02	.02	.03	.04	......	......		
18	200	1 000	2 000	3 000	4 000	5 000	6 000	7 000	......	7 600	.47
	.03	.03	.05	.07	.08	.09	.10	.11	......		
19	500	3 000	6 000	9 000	12 000	15 000	18 000	21 000	24 000	25 400	.23
	.00	.00	.00	.01	.01	.01	.01	.01	.01		
20	500	3 000	6 000	9 000	12 000	15 000	18 000	21 000	......	21 500	.23
	.06	.06	.06	.07	.07	.07	.08	.10	......		
21	200	1 000	2 000	3 000	4 000	5 000	6 000	7 000	......	8 000	.50
	.03	.03	.03	.03	.03	.04	.04	.05	......		
22	500	4 000	8 000	12 000	16 000	20 000	24 000	......	......	27 300	.11
	.00	.00	.00	.00	.00	.00	.00	......	......		
23	300	2 000	4 000	6 000	8 000	......	......	......	......	9 200	.14
	.01	.01	.01	.02	.02	......	......	......	......		
24	500	5 000	10 000	20 000	25 000	30 000	......	......	......	35 000	Crushed.
	.00	.00	.00	.00	.00	.02	......	......	......		
25	300	3 000	6 000	9 000	......	......	......	......	......	11 950	.25
	.01	.01	.01	.02	......	......	......	......	......		
26	......	......	......	......	......	......	......	......	......	9 150	Crushed.
	......	......	......	......	......	......	......	......	......		
27	......	......	......	......	......	......	......	......	......	28 800	Crushed.
	......	......	......	......	......	......	......	......	......		
28	......	......	......	......	......	......	......	......	......	30 650	Crushed.
	......	......	......	......	......	......	......	......	......		
29	Defl	ection	not rec	orded.	......	......	......	......	......	39 425	
30		"	"	"	......	......	......	......	......	22 250	
31	......	10 000	20 000	......	......	......	......	......	......	22 600	
	......	.37	.80	......	......	......	......	......	......		
32	......	10 000	20 000	......	......	......	......	......	......	23 325	
	......	.40	1.18	......	......	......	......	......	......		
33	......	5 000	10 000	15 000	......	......	......	......	......	15 400	
	......	.44	.87	1.50	......	......	......	......	......		
34	......	5 000	10 000	15 000	20 000	25 000	30 000	35 000	......	36 550	
	......	.18	.37	.40	.44	.56	.68	1.12	......		
35	......	5 000	......	......	......	......	......	......	......	7 725	
	......	.50	......	......	......	......	......	......	......		
36	......	......	......	......	......	......	......	......	......	2 910	
	......	......	......	......	......	......	......	......	......		

COMPRESSION TESTS.

Flat-ended Tees.—No. 2.

No.	Shape.	Size.	Length.		Area.	Ultimate Lbs. per Sq. Inch.	$\frac{l}{r}$	Remarks.
		In Inches.	*Ft.*	*In.*	*Sq. In.*			
40	T	3 x 3	8	$0\frac{3}{16}$	2.55	19 020	155	
41	"	$2\frac{1}{2}$ x $2\frac{1}{2}$	8	$0\frac{3}{16}$	1.73	15 896	175	
42	"	2 x 2	8	$0\frac{1}{4}$	.97	12 346	224	
43	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	8	$0\frac{3}{16}$	.54	9 158	301	
44	"	1 x 1	8	$0\frac{1}{4}$	.30	1 923	370	
45	"	3 x 3	6	$6\frac{1}{4}$	2.55	......	126	No failure at 50 000 lbs.
46	"	$2\frac{1}{2}$ x $2\frac{1}{2}$	6	$6\frac{1}{4}$	1.74	17 816	142	
47	"	2 x 2	6	$6\frac{1}{4}$	.97	12 873	182	
48	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	6	$6\frac{5}{16}$	.53	12 195	245	
49	"	1 x 1	6	$6\frac{1}{4}$	.30	2 676	301	
50	"	$2\frac{1}{2}$ x $2\frac{1}{2}$	5	$0\frac{1}{4}$	1.74	28 330	110	
51	"	2 x 2	5	$0\frac{1}{4}$	.99	28 398	140	
52	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	5	$0\frac{3}{16}$	.53	12 596	188	
53	"	1 x 1	5	$0\frac{1}{16}$	.30	6 333	231	
54	"	$2\frac{1}{2}$ x $2\frac{1}{2}$	3	$6\frac{1}{8}$	1.74	......	77	No failure at 50 000 lbs.
55	"	2 x 2	3	$6\frac{1}{8}$	.99	30 272	98	
56	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	3	$6\frac{3}{16}$	.56	34 392	132	
57	"	1 x 1	3	6	.29	16 216	162	
58	"	2 x 2	2	0	.96	39 167	56	
59	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	2	$0\frac{1}{8}$	.56	37 743	75	
60	"	1 x 1	2	$0\frac{1}{8}$	.29	38 584	92	
61	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	1	6	.57	40 526	56	
62	"	1 x 1	1	6	.30	36 667	69	
63	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	1	0	.52	39 810	37	
64	"	1 x 1	1	$0\frac{1}{16}$	.29	40 938	46	
65	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	..	6	.57	49 298	19	
66	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	..	6	.52	45 800	19	
67	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	.	$6\frac{1}{4}$	.52	55 000	19	
68	"	$1\frac{1}{4}$ x $1\frac{1}{4}$	..	$6\frac{1}{8}$	.44	44 500	23	
69	"	1 x 1		6	.28	47 700	23	
70	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	8	$0\frac{1}{4}$	.55	6 360	300	
71	"	1 x 1	8	$0\frac{1}{4}$	.30	2 660	370	
72	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	6	$6\frac{3}{8}$	.54	9 260	244	
73	"	4 x 4	15	$0\frac{3}{8}$	3.65	.....	215	No failure at 50 000 lbs.
74	"	2 x 2	15	$0\frac{1}{2}$	.90	3 200	420	
75	"	3 x 3	15	$0\frac{1}{2}$	2.39	8 840	291	
315	"	2 x 2	2	0	.98	34 900	56	
316	"	2 x 2	1	6	.98	34 980	42	
317	"	2 x 2	1	0	.98	38 800	28	
318	"	2 x 2	..	$6\frac{3}{16}$	.98	50 900	14	

LATERAL DEFLECTIONS OF FLAT-ENDED TEES.

THE UPPER FIGURES REPRESENT PRESSURES IN POUNDS.
THE FIGURES BELOW ARE THE CORRESPONDING DEFLECTIONS IN INCHES.

Number.										Ultimate Pressure.	Permanent Deflection.
40	1 000 .06	5 000 .09	10 000 .12	15 000 .15	20 000 .18	25 000 .20	30 000 .23	35 000 .25	45 000 .41	48 500	1.87
41	1 000 .00	5 000 .12	7 900 .15	9 000 .20	13 000 .28	17 000 .31	21 000 .35	25 000 .40	27 000 .43	27 500	.81
42	500 .07	2 500 .12	5 000 .15	7 000 .18	9 000 .22	11 000 .32	....	....	....	12 000	.56
43	300 .02	1 000 .07	2 000 .08	3 000 .09	4 000 .10	5 000 .40	....	....	....	5 020	.10
44	50 .05	100 .06	150 .11	200 .13	250 .16	300 .17	350 .20	400 .22	500 .41	575	.08
45	500 .05	5 000 .08	10 000 .09	15 000 .10	20 000 .10	25 000 .11	30 000 .11	40 000 .13	50 000 .15	No failure.	
46	500 .05	2 000 .08	6 000 .16	10 000 .20	14 000 .24	18 000 .25	22 000 .27	26 000 .30	30 000 .43	31 000	1.12
47	No l'd .08	500 .15	1 000 .22	2 000 .30	4 000 .36	6 500 .44	8 500 .50	10 500 .64	11 500 .67	12 500	.60
48	100 .03	500 .02	1 000 .03	1 500 .05	2 000 .06	3 000 .09	4 000 .12	5 000 .17	6 000 .31	6 500	.34
49	50 .02	100 .03	150 .04	200 .04	300 .05	400 .06	500 .08	600 .15	700 .35	800	.07
50	500 .08	5 000 .05	10 000 .06	15 000 .06	20 000 .07	25 000 .07	30 000 .08	40 000 .10	45 000 .14	49 300	1.31
51	500 .05	2 000 .05	6 000 .06	10 000 .07	14 000 .08	18 000 .09	22 000 .09	24 000 .10	26 000 .10	28 000	1.12
52	100 .01	500 .03	1 000 .07	2 000 .13	3 000 .17	4 000 .24	5 000 .28	6 000 .36	6 500 .42	6 700	.80
53	100 .02	200 .03	300 .04	600 .05	900 .06	1 200 .07	1 500 .10	1 800 .14	1 900 .18	1 910	.00
54	....	....	....	...... No deflections.	......	......	....	45 000 .02	50 000 .03	No failure.	
55	500 .02	6 000 .02	9 000 .02	12 000 .02	15 000 .02	18 000 .02	21 000 .03	24 000 .03	27 000 .06	30 000	.11
56	500 .02	2 000 .02	4 000 .02	6 000 .03	8 000 .03	12 000 .03	14 000 .04	16 000 .05	18 000 .06	19 500	.95
57	200 .02	1 000 .02	2 000 .02	3 000 .02	3 600 .04	4 000 05	4 200 .07	4 400 .09	4 600 .12	4 800	.14
58	500 .00	5 000 .00	10 000 .01	15 000 .01	20 000 .01	25 000 .01	30 000 .01	35 000 .01	....	37 610	.58
59	500 .00	2 000 .01	6 000 .01	10 000 .01	12 000 .01	14 000 .01	17 000 .02	20 000 .02	....	21 400	.40
60	200 .01	1 000 .01	2 000 .01	3 000 .01	4 000 .01	5 000 .01	6 000 .01	8 000 .02	10 000 .03	11 500	.54
61	500 .01	3 000 .01	6 000 .01	9 000 .01	12 000 .01	15 000 .01	18 000 .01	21 000 .02	....	23 100	.18
62	200 .01	3 000 .01	4 000 .02	5 000 .02	6 000 .02	7 000 .02	8 000 .03	9 000 .03	10 000 .03	11 000	.52
63	500 .00	3 000 .00	6 000 .00	9 000 .00	12 000 .00	15 000 .00	18 000 .03	....	....	20 900	.14
64	500 .00	2 000 .00	4 000 .00	6 000 .00	8 000 .00	10 000 .01	12 000 .02	....	....	12 200	.20
65	500 .00	5 000 .00	10 000 .00	15 000 .00	20 000 .00	25 000 .02	....	....	....	28 100	.06
66	500 .00	5 000 .00	10 000 .00	15 000 .00	20 000 .01	....	....	....	....	23 800	.06
67	......	......	No deflections.			......	......	......	......	28 600	Crushed.
68	......	......	"	"	......	......	......	......	......	19 610	"
69	......	......	"	"	......	......	......	......	......	13 350	"
70	300 .12	1 000 .17	2 000 .22	3 000 .40	....	....	....	....	....	3 500	.47
71	200 .08	300 .08	500 .10	700 .15	....	....	....	....	....	800	.08
72	300 .13	500 .13	1 000 .17	1 500 .19	2 000 .22	2 500 .24	3 000 .27	4 000 .35	5 000 .54	5 000	.62
73	10 000 .21	20 000 .28	30 000 .28	40 000 .31	50 000 .34	....	....	....	....	No failure.	
74	250	2 500 .60	....	....	....	....	....	....	....	2 900	.00
75	500	5 000 .03	10 000 .22	20 000 .47	....	....	....	....	....	21 125	......

COMPRESSION TESTS.

Hinged-Ended Angles.—No. 3.

No.	Shape.	Size.	Length.	Area.	Ultimate Lbs. per Sq. Inch.	$\frac{l}{r}$	Remarks.
		In Inches.	*Ft. Ins.*	*Sq. In.*			
80	Angles.	3 x 3 x $\frac{3}{8}$	8 $4\frac{1}{4}$	2.11	13 199	164	2" ball and socket.
81	"	$2\frac{1}{2}$ x $2\frac{1}{2}$ x $\frac{3}{8}$	8 $4\frac{3}{16}$	1.77	13 898	196	" " " "
82	"	2 x 2 x $\frac{5}{16}$	8 $3\frac{1}{8}$	1.13	3 982	242	1" " " "
83	"	2 x 2 x $\frac{5}{16}$	8 $3\frac{1}{8}$	1.13	7 080	242	Same bar as above, properly centred.
84	"	$1\frac{1}{4}$ x $1\frac{1}{4}$ x $\frac{1}{4}$	8 $3\frac{3}{16}$	.56	4 956	367	1" ball and socket.
85	"	1 x 1 x $\frac{1}{8}$	8 $3\frac{1}{4}$	.24	1 440	496	" " " "
86	"	3 x 3 x $\frac{3}{8}$	6 $10\frac{1}{32}$	2.14	....	134	No failure at 50 000 lbs.
87	"	$2\frac{1}{2}$ x $2\frac{1}{2}$ x $\frac{3}{8}$	6 $10\frac{1}{4}$	1.74	22 989	161	2" ball and socket.
88	"	2 x 2 x $\frac{5}{16}$	6 $9\frac{3}{8}$	1.12	6 964	198	1" " " "
89	"	2 x 2 x $\frac{5}{16}$	6 $9\frac{1}{4}$	1.15	8 087	198	1" " " "
90	"	1 x 1 x $\frac{1}{8}$	6 $9\frac{3}{8}$	.24	1 569	407	1" " " "
91	"	$2\frac{1}{2}$ x $2\frac{1}{2}$ x $\frac{9}{32}$	5 $4\frac{1}{16}$	1.31	27 863	128	2" " " "
92	"	$2\frac{1}{2}$ x $2\frac{1}{2}$ x $\frac{9}{32}$	5 $4\frac{1}{16}$	1.31	18 321	128	1" " " "
93	"	$2\frac{1}{2}$ x $2\frac{1}{2}$ x $\frac{3}{8}$	5 $4\frac{3}{8}$	1.78	22 191	126	2" " " "
94	"	2 x 2 x $\frac{5}{16}$	5 $3\frac{1}{4}$	1.13	10 619	154	1" " " "
95	"	1 x 1 x $\frac{1}{8}$	5 3	.23	5 769	315	1" " " "
96	"	1 x 1 x $\frac{1}{8}$	5 $3\frac{3}{16}$	.24	2 929	316	Slightly out of centre.
97	"	$2\frac{1}{2}$ x $2\frac{1}{2}$ x $\frac{3}{8}$	3 $10\frac{3}{16}$	1.74	27 759	91	2" ball and socket.
98	"	2 x 2 x $\frac{5}{16}$	3 $9\frac{1}{8}$	1.15	15 826	110	1" " " "
99	"	1 x 1 x $\frac{1}{8}$	3 $9\frac{1}{16}$	.23	11 454	225	1" " " "
100	"	$2\frac{1}{2}$ x $2\frac{1}{2}$ x $\frac{3}{8}$	2 $4\frac{1}{16}$	1.74	....	56	No failure at 50 000 lbs.
101	"	2 x 2 x $\frac{5}{16}$	2 $3\frac{1}{16}$	1.14	27 632	66	1" ball and socket.
102	"	1 x 1 x $\frac{1}{8}$	2 3	.24	31 660	135	1" " " "
103	"	1 x 1 x $\frac{1}{8}$	1 $11\frac{13}{16}$	.24	38 600	119	1" " " "
104	"	$1\frac{1}{2}$ x $1\frac{1}{2}$ x $\frac{1}{4}$	1 9	.67	35 821	68	1" " " "
105	"	1 x 1 x $\frac{1}{8}$	1 9	.24	36 250	105	1" " " "
106	"	1 x 1 x $\frac{1}{8}$	1 $8\frac{11}{16}$	.23	38 600	103	1" " " "
107	"	$1\frac{1}{2}$ x $1\frac{1}{2}$ x $\frac{1}{4}$	1 3	.71	36 880	48	1" " " "
108	"	1 x 1 x $\frac{1}{8}$	1 $3\frac{1}{8}$	.24	42 194	76	1" " " "
109	"	1 x 1 x $\frac{1}{8}$	1 $2\frac{13}{16}$	.23	42 500	74	1" " " "
110	"	1 x 1 x $\frac{1}{8}$	9	.27	41 482	45	1" " " "
111	"	$1\frac{1}{2}$ x $1\frac{1}{2}$ x $\frac{1}{4}$	9	.66	42 576	29	1" " " "
112	"	1 x 1 x $\frac{1}{8}$	$6\frac{7}{8}$	.23	41 200	34	1" pins
113	"	$1\frac{1}{4}$ x $1\frac{1}{4}$ x $\frac{1}{4}$	$6\frac{13}{16}$	.56	44 330	25	1" "
114	"	$1\frac{1}{2}$ x $1\frac{1}{2}$ x $\frac{1}{4}$	$6\frac{9}{16}$	.66	43 520	21	1" "
115	"	4 x 4 x $\frac{3}{8}$	15 $4\frac{9}{16}$	2.81	4 980	234	2" ball and socket.
116	"	4 x 4 x $\frac{3}{8}$	15 $4\frac{1}{2}$	2.83	4 780	231	2" pins.
117	"	4 x 3 x $\frac{15}{32}$	15 $5\frac{3}{8}$	3.06	7 020	290	2" ball and socket.
118	"	$2\frac{3}{4}$ x $2\frac{3}{4}$ x $\frac{3}{8}$	10 $10\frac{1}{4}$	1.93	8 650	233	2" " " "
119	"	$3\frac{1}{2}$ x $3\frac{1}{2}$ x $\frac{3}{8}$	10 $10\frac{1}{4}$	2.42	15 770	189	2" " " "
120	"	3 x 3 x $\frac{7}{16}$	15 $3\frac{3}{4}$	2.52	5 970	329	2" " " "
121	"	Same Bar.	15 $3\frac{3}{4}$	2.52	2 940	329	1" " " "
122	"	2 x 2 x $\frac{5}{16}$	15 $4\frac{3}{16}$	1.12	1 600	449	2" " " "
123	"	Same Bar.	15 $4\frac{3}{16}$	1.12	1 380	449	1" " " "
124	"	3 x 3 x $\frac{7}{16}$	15 $1\frac{15}{16}$	2.52	5 600	325	2" pins.
125	"	4 x 4 x $\frac{3}{8}$	15 $2\frac{3}{8}$	2.81	15 100	231	2" "
126	"	4 x 3 x $\frac{15}{32}$	15 $5\frac{3}{8}$	3.06	8 820	290	2" "

LATERAL DEFLECTIONS OF HINGED-ENDED ANGLES.

THE UPPER FIGURES REPRESENT PRESSURES IN POUNDS.

THE LOWER FIGURES ARE THE CORRESPONDING DEFLECTIONS IN INCHES.

Number.										Ultimate Pressure.	Permanent Deflection.
80	500	5 000	10 000	15 000	20 000	25 000	......	......	......	27 850	.20
	.02	.05	.07	.09	.12	.18	......	......	......		
81	500	5 000	10 000	15 000	20 000	......	......	......	......	24 600	.33
	.02	.03	.04	.06	.11	......	......	......	......		
82	500	2 000	4 000	......	......	......	......	......	......	4 500	.05
	.04	.07	.30	......	......	......	......	......	......		
83	500	1 000	2 000	3 000	4 000	5 000	6 000	7 000	......	8 100	.05
	.0	.04	.04	.04	.03	.03	.05	.05	......		
84	100	400	800	1 200	1 600	2 000	2 400	......	......	2 800	.00
	.05	.06	.07	.07	.07	.07	.07	......	......		
85	100	200	300	......	......	......	......	......	......	350	.00
	.03	.06	.13	......	......	......	......	......	......		
86	500	10 000	15 000	20 000	25 000	30 000	35 000	40 000	50 000	No failure	.00
	.02	.03	.03	.03	.04	.04	.05	05	.06		
87	500	5 000	10 000	15 000	20 000	25 000	30 000	34 000	38 000	40 000	......
	.03	.05	04	.04	.04	.05	.05	.07	.10		
88	500	3 000	6 000	......	......	......	......	......	......	7 800	.05
	.03	.04	.08	......	......	......	......	......	......		
89	500	3 000	6 000	9 000	......	......	......	......	......	9 300	.05
	.02	.03	.04	.22	......	......	......	......	......		
90	100	200	300	......	......	......	......	......	......	375	.00
	.11	.13	.17	......	......	......	......	......	......		
91	500	3 000	6 000	12 000	18 000	24 000	30 000	33 000	36 000	36 500	1.00
	.03	.03	.03	.03	.03	.02	.03	.04	.07		
92	500	3 000	6 000	9 000	12 000	15 000	18 000	21 000	24 000	24 010	.64
	.02	.03	.03	.03	.03	.04	.05	.11	.64		
93	500	3 000	9 000	15 000	21 000	27 000	33 000	36 000	39 000	39 500	.75
	.02	.07	.03	.05	.07	.10	.13	.16	.24		
94	500	3 000	6 000	9 000	12 000	......	......	......	......	12 010	.48
	.03	.03	.04	.05	.07	......	......	......	......		
95	100	300	400	500	600	700	800	1 000	1 300	1 350	.00
	.02	03	.03	.04	.04	.05	.05	.05	.05		
96	100	300	500	600	......	......	......	......	......	700	.00
	.02	.02	.03	.45	......	......	......	......	......		
97	500	10 000	15 000	20 000	25 000	30 000	35 000	40 000	45 000	48 300	.64
	.02	.03	.03	.04	.04	.05	.05	.07	.09		
98	500	4 000	8 000	12 000	16 000	......	......	......	......	18 200	.50
	.01	.02	.03	.08	.19	......	......	......	......		
99	200	600	1 000	1 400	1 800	3 000	2 200	2 400	......	2 600	.03
	.02	.02	.02	.02	.03	03	.03	.05	......		
100	500										
	.01	No deflection and no failure with 50 000 lbs.									
101	500	5 000	10 000	15 000	20 000	25 000	30 000	......	......	31 500	.30
	.00	.01	.01	.01	.02	.03	.03	......	......		
102	200	1 000	2 000	3 000	4 000	5 000	6 000	7 000	......	7 600	.31
	.05	.06	.06	.07	.07	.07	.09	.10	......		
103	500	1 000	2 000	3 000	4 000	5 000	6 000	7 000	8 000	9 000	.28
	.02	.03	.03	.03	.03	.03	.03	.03	.05		
104	500	3 000	6 000	9 000	12 000	15 000	18 000	21 000	......	24 000	.28
	.01	.01	.01	.01	.01	.01	.01	.02	......		
105	200	1 000	2 000	3 000	4 000	5 000	6 000	7 000	8 000	8 700	.46
	.02	.02	.02	.02	.02	.02	.02	.02	.03		
106	500	1 000	2 000	3 000	4 000	5 000	6 000	7 000	8 000	9 000	.28
	.02	.03	.03	.03	.03	.03	.03	.03	.05		
107	500	4 000	8 000	12 000	16 000	20 000	24 000	......	......	26 000	.21
	.01	.01	.01	.01	.01	.01	.01	......	......		
108	300	2 000	4 000	6 000	8 000	10 000	......	......	......	10 010	.29
	.01	.01	.01	.01	.01	.03	......	......	......		
109	500	2 000	4 000	6 000	8 000	......	......	......	......	9 900	.27
	.01	.01	.01	.01	.02	......	......	......	......		
110	300	3 000	6 000	9 000	......	......	......	......	......	11 200	.17
	.01	.01	.01	.01	......	......	......	......	......		

LATERAL DEFLECTION—(*Continued*).

Number.										Ultimate Pressure.	Permanent Deflection.
111	......	....	No d	eflectio	n with	25 000	lbs.	....	....	28 100	.21
112	......	....	"	"	"	"	"	....	....	9 475	Crushed.
113	......	......	"	"	"	"	"	....	....	24 825	"
114	......	....	"	"	"	"	"	....	....	28 725	"
115	......	5 000	10 000	....	....	....	....	....	....	14 000	.00
	......	.09	.22	....	....	....	....	....	....		
116	......	5 000	10 000	....	....	....	....	....	....	13 800	.00
	......	.12	.31	....	....	....	....	....	....		
117	......	10 000	20 000	....	....	....	....	....	....	21 500	.00
	......	.06	.18	....	....	....	....	....	....		
118	......	....	....	....	....	....	....	....	....	16 700	.00
119	.....	....	....	....	....	....	....	....	....	38 175	.00
120	......	5 000	10 000	....	....	....	....	....	....	14 925	.00
	......	.06	.12	....	....	....	....	....	....		
121	......	5 000	....	....	....	....	....	....	....	7 400	.00
	......	.16	....	....	....	....	....	....	....		
122	......	....	....	....	....	....	....	....	....	1 900	.00
123	.....	.....	....	....	....	.....	....	....	....	1 550	.00
124	......	5 000	10 000	....	....	....	....	....	....	14 000	.00
	......	.06	.19	....	....	....	....	....	....		
125	.....	5 000	15 000	25 000	35 000	40 000	....	....	....	42 425	.00
	......	.06	.06	.06	.03	.19	....	....	....		
126	......	10 000	20 000	....	....	....	....	....	....	27 020	.00
	......	.00	03	....	....	....	....	....	....		

COMPRESSION TESTS.

Hinged-Ended Tees.—No. 4.

No.	Shape.	Size.	Length.		Area.	Ultimate Lbs. per Sq. Inch.	$\frac{l}{r}$	Remarks.
		In Inches.	*Ft.*	*Ins.*	*Sq. In.*			
130	T	3 x 3	8	$4\frac{1}{8}$	2.47	13 117	161	2″ ball and socket.
131	"	$2\frac{1}{2}$ x $2\frac{1}{2}$	8	$4\frac{3}{8}$	1 74	11 207	182	2″ " " "
132	"	2 x 2	8	$3\frac{1}{4}$	.97	10 597	231	1″ " " "
133	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	8	$3\frac{1}{4}$	.53	4 672	310	1″ " " "
134	"	1 x 1	8	$3\frac{3}{16}$	.30	2 425	381	1″ " " "
135	"	3 x 3	6	$10\frac{7}{16}$	2.54	......	133	No failure at 50 000 lbs.
136	"	$2\frac{1}{2}$ x $2\frac{1}{2}$	6	$10\frac{1}{4}$	1.74	16 379	150	2″ ball and socket.
137	"	2 x 2	6	$9\frac{3}{8}$	.98	11 495	189	1″ " " "
138	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	6	$9\frac{3}{8}$	.54	9 870	254	1″ " " "
139	"	1 x 1	6	$9\frac{3}{16}$	.29	2 542	312	1″ " " "
140	"	$2\frac{1}{2}$ x $2\frac{1}{2}$	5	$4\frac{1}{8}$	1.74	17 529	117	2″ " " "
141	"	2 x 2	5	$3\frac{1}{8}$	.96	19 311	147	1″ " " "
142	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	5	$3\frac{3}{16}$	.53	11 278	197	1″ " " "
143	"	1 x 1	5	$3\frac{3}{16}$	.30	4 660	243	1″ " " "
144	"	$2\frac{1}{2}$ x $2\frac{1}{2}$	3	$10\frac{1}{8}$	1.74	27 874	84	2″ " " "
145	"	2 x 2	3	$9\frac{1}{8}$	.96	21 532	105	1″ " " "
146	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	3	9	.54	14 925	141	1″ " " "
147	"	$2\frac{1}{2}$ x $2\frac{1}{2}$	3	$10\frac{1}{8}$	1.74	28 736	84	2″ " " "
148	"	1 x 1	3	$9\frac{1}{4}$	.30	10 067	174	1″ " " "
149	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	3	$9\frac{1}{8}$	.55	19 100	141	1″ " " "
150	"	$1\frac{1}{4}$ x $1\frac{1}{4}$	3	$9\frac{3}{16}$	.46	19 100	167	1″ " " "
151	"	2 x 2	3	$9\frac{1}{8}$	.96	21 460	105	1″ " " "
152	"	$2\frac{1}{2}$ x $2\frac{1}{2}$	2	$4\frac{1}{16}$	1.74	......	51	No failure at 50 000 lbs.
153	"	2 x 2	2	3	.96	32 292	63	1″ ball and socket.
154	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	2	3	.53	29 524	84	1″ " " "
155	"	$1\frac{1}{4}$ x $1\frac{1}{4}$	1	11	.46	36 300	85	1″ " " "
156	"	1 x 1	1	$11\frac{1}{4}$	.31	34 200	89	1″ " " "
157	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	1	9	.57	36 667	66	1″ " " "
158	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	1	$11\frac{1}{8}$	.52	22 690	72	1″ ball and socket, retested bar.
159	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	1	3	.51	36 765	47	1″ ball and socket.
160	"	$1\frac{1}{2}$ x $1\frac{1}{2}$		$9\frac{1}{8}$	.56	47 846	29	1″ " " "
161	"	$1\frac{1}{2}$ x $1\frac{1}{2}$		$8\frac{15}{16}$	.56	43 850	28	1″ " " "
162	"	$1\frac{1}{2}$ x $1\frac{1}{2}$		$6\frac{5}{8}$	.52	45 860	21	1″ pin.
163	"	$1\frac{1}{4}$ x $1\frac{1}{4}$		$6\frac{7}{8}$	.44	37 600	25	1″ "
164	"	1 x 1		$6\frac{11}{16}$	.28	43 750	26	1″ "
165	"	$1\frac{1}{4}$ x $1\frac{1}{4}$	8	$6\frac{3}{16}$	.45	2 440	378	1″ ball and socket.
166	"	4 x 4	15	$2\frac{3}{8}$	3.65	......	217	No failure at 50 000 lbs.
167	"	3 x 3	15	$1\frac{3}{4}$	2.38	9 870	293	2″ pin.
168	"	2 x 2	15	$3\frac{3}{4}$	.90	1 780	427	1″ ball and socket.

LATERAL DEFLECTIONS OF HINGED-ENDED TEES.

THE UPPER FIGURES REPRESENT PRESSURES IN POUNDS.

THE FIGURES BELOW ARE THE CORRESPONDING DEFLECTIONS IN INCHES.

Number.										Ultimate Pressure.	Permanent Set.
130	500	5 000	10 000	15 000	20 000	25 000	30 000	......	......	32 400	.48
	.03	.03	.04	.05	.06	.10	.25	......	......		
131	500	3 000	6 000	9 000	12 000	15 000	18 000	......	......	19 500	.43
	.03	.05	.06	.07	.08	.13	.25	......	......		
132	509	1 000	3 000	5 000	6 000	7 000	8 000	9 000	10 000	10 300	.08
	.04	.05	.05	.05	.05	.06	.07	.10	.16		
133	500	1 000	1 500	2 000	......	......	......	......	......	2 500	.00
	.03	.03	.04	.05	......	......	......	......	......		
134	100	200	300	400	500	600	700	......	......	725	.05
	.05	.06	.07	.08	.09	.11	.20	......	......		
135	500	5 000	15 000	25 000	30 000	35 000	40 000	45 000	50 000	No failure	.07
	.02	.04	.05	.06	.06	.07	.07	.08	.10		
136	500	5 000	10 000	15 000	20 000	23 500	25 000	......	......	28 500	1.03
	.03	.03	.03	03	.04	.09	.13	......	......		
137	500	2 000	4 000	6 000	7 000	8 000	9 000	10 000	11 000	11 300	.15
	.03	.04	.05	.06	.06	.07	.08	.11	.14		
138	500	1 000	2 000	2 500	3 000	3 500	4 000	4 500	5 000	5 300	.07
	.02	.02	.02	.02	.03	.04	.05	.07	.09		
139	100	200	300	400	500	550	600	650	700	750	.00
	.03	.04	05	.06	.07	.07	.08	.13	.17		
140	500	5 000	10 000	15 000	20 000	25 000	30 000	......	......	30 500	.88
	.00	.01	.02	.02	.04	.07	.20	......	......		
141	500	4 000	6 000	8 000	10 009	12 000	14 000	16 000	18 000	18 500	.62
	.03	.03	.03	.03	.03	03	.03	.04	.10		
142	100	1 000	2 000	3 000	4 000	5 000	......	......	......	6 000	.00
	.02	......	No fur	ther d	eflectio	n.	......	......	......		
143	100	200	400	600	800	1 000	1 200	1 300	1 400	1 410	.00
	.05	.06	.08	.08	.09	.10	.11	.12	.18		
144	500	10 000	15 000	20 000	25 000	30 000	35 000	40 000	45 000	48 500	.90
	.00	.00	.00	.02	.02	03	.03	.03	.05		
145	500	4 000	8 000	10 000	12 000	14 000	16 000	18 000	20 000	20 800	.44
	.02	.03	.05	.06	.07	.08	.10	.12	.16		
146	500	1 000	2 000	3 000	4 000	5 000	6 000	7 000	8 000	8 010	.75
	.01	.01	.01	.02	.03	.04	.05	.16	.26		
147	500	10 000	20 000	25 000	30 000	35 000	40 000	45 000	50 000	50 000	.78
	.02	.03	.03	.04	.05	.05	.05	,06	.10		
148	200	1 000	1 600	1 800	2 000	2 200	2 400	2 600	2 800	3 000	.00
	.02	.02	.02	.03	.03	.03	.03	.04	.04		
149	500	2 000	4 000	6 000	8 000	10 000	......	......	......	10 520	.34
	.03	.03	.04	05	.06	.09	......	......	......		
150	500	2 000	4 000	6 000	8 000	......	......	......	......	8 800	.35
	.02	.02	.02	02	.02	......	......	......	......		
151	500	5 000	10 000	15 000	20 000	......	......	......	......	20 610	.72
	.03	.04	.06	.08	.11	......	......	......	......		
152	500	10 000	20 000	30 000	40 000	50 000	......	......	......	No failure	.02
	01	.01	.01	.02	.02	.03	......	......	......		
153	500	5 000	10 000	20 000	30 000	......	......	......	......	30 990	.39
	,02	.02	.02	.02	03	......	......	......	......		
154	500	3 000	6 000	9 000	12 000	15 000	......	......	......	15 450	.50
	.02	.02	.03	.04	05	.07	......	......	......		
155	500	1 000	3 000	6 000	9 000	12 000	14 000	16 000	......	16 710	.32
	.01	.02	02	.03	.03	.04	.04	.05	......		
156	500	5 000	7 000	8 000	9 000	10 000	......	......	......	10 550	.26
	.01	.01	.01	.02	.02	.03	......	......	......		
157	500	......	......	......	......	15 000	18 000	......	......	20 966	.38
	.02	No d	eflectio	n up	to	.03	.03	......	......		
158	500	8 000	10 000	......	......	......	......	......	......	11 775	.29
	.02	.02	.04	......	......	......	......	......	......		
159	500	......	......	......	......	18 000	......	......	......	18 750	.19
	.00	No d	eflectio	n up	to	.02	......	......	......		
160	500	......	......	......	......	25 000	......	......	......	26 720	.10
	.00	No d	eflectio	n up	to	.02	......	......	......		
161	500	......	......	......	......	......	......	......	......	22 800	.20
	.00	No d	eflectio	n befor	e failu	re.	......	......	......		

LATERAL DEFLECTIONS—(*Continued*).

Number.										Ultimate Pressure.	Permanent Set.
162	......	......	......	......	......	......	......	......	......	23 850	......
163	......	......	......	......	......	......	......	......	......	16 550	......
164	......	......	......	......	......	......	......	......	......	12 260	......
165	300 .10	500 .15	700 .22	900 .25	....	....	....	....	....	1 100	.00
166	....	5 000 .00	10 000 .03	15 000 .06	25 000 .09	35 000 .12	45 000 .18	50 000 .25	....	No failure	.00
167	....	5 000 .00	15 000 .06	....	....	....	....	....	....	23 490	.00
168	......	......	......	......	......	......	......	......	......	1 610	......

COMPRESSION TESTS.

Fixed-ended Angles.—No. 5.

No.	Shape.	Size.	Length.		Area.	Ultimate Lbs per Sq. Inch.	$\frac{l}{r}$	Remarks.
		In Inches.	*Ft.*	*In.*	*Sq. In.*			
170	Angles.	$3 \times 3 \times \frac{3}{8}$	7	$5\frac{5}{8}$	2.04	19 461	147	
171	"	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$	7	$5\frac{11}{16}$	1.77	20 791	176	
172	"	$2 \times 2 \times \frac{5}{16}$	7	$5\frac{1}{2}$	1.13	14 159	218	
173	"	$1 \times 1 \times \frac{1}{8}$	7	$5\frac{3}{4}$	.24	4 115	449	
174	"	$3 \times 3 \times \frac{3}{8}$	5	$11\frac{11}{16}$	2.08	......	118	No failure at 50 000 lbs.
175	"	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$	5	$11\frac{13}{16}$	1.78	21 461	141	
176	"	$2 \times 2 \times \frac{5}{16}$	5	$11\frac{7}{8}$	1.13	19 027	175	
177	"	$1 \times 1 \times \frac{1}{8}$	5	$11\frac{7}{8}$	.24	6 996	359	
178	"	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$	4	$5\frac{5}{8}$	1.74	27 529	105	
179	"	$2 \times 2 \times \frac{5}{16}$	4	$5\frac{13}{16}$	1.12	24 107	131	
180	"	$1 \times 1 \times \frac{1}{8}$	4	$5\frac{5}{8}$	.23	10 684	268	
181	"	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$	2	$11\frac{11}{16}$	1.77	28 249	70	
182	"	$2 \times 2 \times \frac{5}{16}$	3	0	1.16	33 362	88	
183	"	$1 \times 1 \times \frac{1}{8}$	2	$11\frac{9}{16}$	.23	23 377	178	
184	"	$2 \times 2 \times \frac{5}{16}$	1	$5\frac{1}{2}$	1.14	29 386	43	
185	"	$1 \times 1 \times \frac{1}{8}$	1	$5\frac{5}{8}$	.24	35 566	88	
186	"	$1 \times 1 \times \frac{1}{8}$		$11\frac{5}{8}$	.24	38 333	58	
187	"	$1\frac{1}{2} \times 1\frac{1}{2} \times \frac{1}{4}$		$5\frac{1}{2}$	.70	43 617	18	
188	"	$1 \times 1 \times \frac{1}{8}$		$5\frac{1}{2}$	.24	45 781	28	
189	"	$4 \times 4 \times \frac{3}{8}$	14	$5\frac{1}{2}$	2.81	15 900	221	
190	"	$4 \times 4 \times \frac{3}{8}$	14	$6\frac{1}{2}$	2.83	13 600	221	
191	"	$3 \times 3 \times \frac{5}{16}$	14	$6\frac{3}{8}$	2.47	8 690	312	
192	"	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$	14	$6\frac{3}{8}$	1.72	6 260	341	Retested bar, see No. 35.
193	"	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$	14	$6\frac{1}{4}$	1.64	7 900	341	
194	"	$2 \times 2 \times \frac{5}{16}$	14	$6\frac{1}{8}$	1.12	4 460	439	Retested bar, see No. 36.
195	"	$2 \times 2 \times \frac{5}{16}$	14	$6\frac{1}{4}$	1.12	4 600	439	

LATERAL DEFLECTIONS OF FIXED-ENDED ANGLES.

THE UPPER FIGURES REPRESENT PRESSURES IN POUNDS.

THE FIGURES BELOW ARE THE CORRESPONDING DEFLECTIONS IN INCHES.

Number.										Ultimate Pressure.	Permanent Set.
170	500	5 000	10 000	15 000	20 000	25 000	30 000	35 000	....	39 700	.18
	.03	.07	.08	.09	.09	.10	.13	.17	....		
171	500	5 000	10 000	15 000	20 000	25 000	30 000	35 000	....	36 790	.64
	.01	.03	.05	.06	.07	.10	.14	.24	....		
172	500	3 000	6 000	9 000	12 000	15 000	....	....	....	16 020	.55
	.04	.09	.12	.15	.20	.39	....	....	....		
173	100	200	300	400	500	600	700	800	900	1 000	.14
	.14	.23	.28	.33	.39	.47	.57	.66	.80		
174	500	5 000	10 000	....	....	....	....	....	[lbs.	....	.00
	.03	.03	.04	No defl	ection	and no	failure	with	50 000		
175	500	5 000	10 000	20 000	25 000	30 000	35 000	....	....	38 200	.20
	.01	.02	.03	.03	.04	.06	.07	....	....		
176	500	3 000	6 000	9 000	12 000	15 000	18 000	21 000	....	21 480	.59
	.09	.13	.15	.17	.20	.23	.30	.45	....		
177	200	400	600	800	1 000	1 200	1 400	1 500	1 600	1 700	.12
	.05	.08	.10	.12	.16	.20	.25	.30	.50		
178	500	5 000	10 000	20 000	30 000	35 000	40 000	45 000	....	47 900	.48
	.03	.04	.05	.06	.06	.07	.08	.11	....		
179	500	3 000	6 000	9 000	12 000	15 000	18 000	21 000	24 000	27 000	.21
	.04	.05	.06	.07	.07	.08	.09	.10	.13		
180	100	400	700	1 000	1 300	1 600	1 900	2 200	....	2 500	.12
	.05	.05	.08	.09	.13	.15	.22	.35	....		
181	500	10 000	20 000	30 000	40 000	45 000	....	....	....	50 000	.15
	.03	.03	.04	.04	.05	.08	Parti	al failu	re.		
182	500	....	....	....	....	....	36 000	....	....	38 710	....
	.00		No d	eflectio	n up	to	.02	....	....		
183	100	200	300	400	1 000	2 000	3 000	4 000	5 200	5 400	1.25
	.01	.02	.03	.05	.07	.07	.08	.08	.09		
184	500	15 000	20 000	30 000	....	.....	....	....	....	33 520	.15
	.01	.01	.02	.03	....	....	....	....	....		
185	200	2 000	4 000	6 000	8 000	....	....	....	....	8 500	.28
	.01	.02	.02	.02	.03	....	....	....	....		
186	200	1 000	....	....	....	....	9 000	....	....	9 200	.17
	.01	.02	No d	eflectio	n up	to	.03	....	....		
187	500	4 000	....	....	....	.....	28 000	....	....	30 750	.17
	.00	.01	No d	eflectio	n up	to	.04	....	....		
188	300	....	....	....	....	....	8 000	10 000	....	10 860	.15
	.01		No d	eflectio	n up	to	.02	.02	....		
189	......	10 000	20 000	30 000	40 000	....	....	....	....	44 650	....
	......	00	.06	.12	.37	....	....	....	....		
190	......	10 000	20 000	30 000	....	....	....	....	....	38 400	.88
	......	.31	.37	.62	....	....	....	....	....		
191	......	5 000	10 000	20 000	....	....	....	....	....	21 475	.25
	......	.06	.22	.50	....	....	....	....	....		
192	......	5 000	10 000	....	....	....	....	....	....	10 775	.37
	......	,37	.50	....	....	....	....	....	....		
193	......	5 000	10 000	....	....	....	....	....	....	12 950	.38
	......	.56	.87	....	....	....	....	....	....		
194	......	4 500	....	....	....	....	....	....	....	5 000	.00
	......	.56	....	....	....	....	....	....	....		
195	......	2 500	5 000	....	....	....	....	....	....	5 150	.00
	......	.06	1.56	....	....	....	....	....	....		

COMPRESSION TESTS.

Round-ended Tees and Angles.—No. 6.

No.	Shape.	Size.	Length.		Area.	Ultimate Lbs. per Sq. Inch.	$\frac{l}{r}$	Remarks.
		In Inches.	*Ft.*	*Ins.*	*Sq. In.*			
200	T	3 x 3	8	$4\frac{1}{4}$	2.56	12 305	162	2″ ball and plate.
201	"	$2\frac{1}{2}$ x $2\frac{1}{2}$	8	$4\frac{5}{16}$	1.74	7 874	182	2″ " "
202	"	2 x 2	8	$3\frac{1}{4}$	.99	4 863	231	1″ " "
203	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	8	3	.53	2 476	309	1″ " "
204	"	1 x 1	8	$3\frac{1}{4}$	.30	1 815	382	1″ " "
205	"	3 x 3	6	$10\frac{1}{16}$	2.53	13 478	132	2″ " "
206	"	$2\frac{1}{2}$ x $2\frac{1}{2}$	6	$10\frac{3}{8}$	1.73	12 428	150	2″ " "
207	"	2 x 2	6	$9\frac{3}{16}$	.97	7 239	189	1″ " "
208	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	6	$9\frac{3}{16}$	.53	4 120	254	1″ " "
209	"	1 x 1	6	$9\frac{1}{2}$	.30	2 016	313	1″ " "
210	"	$2\frac{1}{2}$ x $2\frac{1}{2}$	5	$4\frac{1}{4}$	1.75	13 714	117	2″ " "
211	"	2 x 2	5	$3\frac{3}{16}$	.95	10 053	147	1″ " "
212	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	5	$3\frac{1}{4}$	.57	7 840	198	1″ " "
213	"	1 x 1	5	$3\frac{1}{8}$	.30	3 340	243	1″ " "
214	"	$2\frac{1}{2}$ x $2\frac{1}{2}$	3	$10\frac{3}{16}$	1.74	24 138	84	2″ " "
215	"	2 x 2	3	$9\frac{1}{8}$	1.00	22 200	105	1″ " "
216	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	3	$9\frac{3}{16}$	.57	13 112	141	1″ " "
217	"	1 x 1	3	$9\frac{1}{4}$	.30	5 872	174	1″ " "
218	"	$2\frac{1}{2}$ x $2\frac{1}{2}$	2	$4\frac{1}{8}$	1.74	28 300	51	2″ " "
219	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	2	3	.54	25 370	84	1″ " "
220	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	1	9	.57	32 900	66	1″ " "
221	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	1	3	.53	37 143	47	1″ " "
222	"	$1\frac{1}{2}$ x $1\frac{1}{2}$	1	3	.53	32 000	47	Same bar as above. 1″ ball and plate.
223	"	$1\frac{1}{2}$ x $1\frac{1}{2}$		$9\frac{1}{16}$	.56	41 135	28	1″ " "
224	"	3 x 3	6	$10\frac{7}{16}$	2.54	15 748	133	2″ " "
225	"	3 x 3	15	$4\frac{1}{2}$	2.43	3 340	298	2″ " "
226	"	2 x 2	15	$3\frac{1}{4}$	.88	1 140	426	1″ " "
227	Angle	3 x 3 x $\frac{7}{16}$	15	$4\frac{1}{4}$	2.52	3 000	329	2″ " "
228	"	Same bar.	15	$4\frac{1}{4}$	2.52	2 740	329	1″ " "
229	"	2 x 2 x $\frac{5}{16}$	15	$3\frac{3}{16}$	1.12	1 280	447	1″ " "

LATERAL DEFLECTIONS OF ROUND-ENDED TEES AND ANGLES.

THE UPPER FIGURES REPRESENT PRESSURES IN POUNDS.

THE FIGURES BELOW ARE THE CORRESPONDING DEFLECTIONS IN INCHES.

Number.										Ultimate Pressure.	Permanent Set.
200	500	10 000	15 000	20 000	25 000	30 000	......	......	......	31 490	.00
	.05	.05	.06	.07	.11	.32	......	......	......		
201	500	2 000	4 000	6 000	8 000	10 000	12 000	......	......	13 700	.20
	.04	.04	.05	.08	.10	.15	.26	......	......		
202	500	1 000	2 000	3 000	4 000	.	......	......	......	4 780	.08
	.03	.04	.06	.11	.25	......	......	......	......		
203	200	500	1 000	......	......	......	......	......	......	1 300	.00
	.06	.08	,24	......	......	......	......	......	......		
204	100	200	300	400	500	......	......	......	......	550	.00
	.05	.05	.08	.15	.30	......	......	......	......		
205	500	5 000	10 000	15 000	20 000	25 000	30 000	......	......	34 110	.65
	.03	.04	.05	.05	.06	.09	.15	......	......		
206	500	3 000	6 000	9 000	12 000	15 000	18 000	20 000	21 000	21 510	.70
	.03	.05	.06	.07	.10	.12	.16	.22	.30		
207	500	1 000	2 000	3 000	4 000	5 000	6 000	6 500	......	7 000	.52
	.02	.03	.04	.04	.06	.11	.21	.35	......		
208	200	600	800	1 000	1 200	1 400	1 600	1 800	2 000	2 200	.18
	.02	.05	.06	.07	.09	.12	.15	.20	.30		
209	100	200	300	400	500	......	......	......	......	600	.00
	.02	.05	.10	.15	.25	......	......	......	......		
210	500	5 000	10 000	15 000	20 000	......	......	......	......	23 990	.80
	.00	.03	.05	.08	.12	......	......	......	......		
211	500	2 000	3 000	4 000	5 000	6 000	7 000	8 000	9 000	9 510	.48
	.03	.05	.06	.08	.10	.15	.20	.27	.40		
212	500	2 000	3 000	4 500	......	......	......	......	......	4 510	.29
	.00	.03	.09	.60	......	......	......	......	......		
213	100	300	.500	700	900	......	......	......	......	1 010	.09
	.01	.02	.03	.10	.33	......	......	......	......		
214	500	5 000	10 000	15 000	20 000	40 000	......	......	......	42 000	.73
	.00	.01	.01	.02	.03	.03	......	......	......		
215	500	3 000	6 000	9 000	15 000	18 000	......	......	......	21 190	.22
	,02	.02	.02	.03	.04	.08	......	.	......		
216	500	2 000	4 000	6 000	......	......	......	......	......	7 500	.42
	.00	.00	.03	.09	......	......	......	......	......		
217	100	400	600	800	1 000	1 200	1 400	1 600	1 700	1 750	.20
	.01	.02	.03	.04	.06	.10	.15	.29	.55		
218	500	10 000	20 000	30 000	35 000	45 000	......	......	......	49 290	.50
	.02	.02	.02	.02	.03	.03	......	......	......		
219	500	3 000	6 000	9 000	12 000	......	......	......	......	13 725	.45
	.01	.01	.02	.03	.05	......	......	......	......		
220	500	6 000	12 000	15 000	18 000	......	......	......	......	18 820	.38
	.02	.02	.03	.03	.05	......	......	......	......		
221	500	......	......	......	......	18 000	......	......	......	19 500	.37
	.00	No d	eflectio	n up	to	.01	......	......	......		
222	500	......	......	......	......	12 000	15 000	......	......	16 820	.21
	.00	No d	eflectio	n up	to	.01	.01	......	......		
223	500	......	......	......	......	......	......	......	......	23 200	......
	.00	No d	eflectio	n, bar	crushe	d......	......	......	......		
224	500	10 000	20 000	25 000	30 000	35 000	40 000	......	......	40 010	.47
	.07	.07	.08	09	.10	.11	.40	......	......		
225	......	5 000	......	......	......	......	......	......	......	8 125	.00
	......	.06	......	......	......	......	......	......	......		
226	......	......	......	......	......	......	......	......	......	1 000	.00
227	......	5 000	......	......	......	......	......	......	......	7 575	.00
	......	.31	......	......	......	......	......	......	......		
228	......	5 000	......	......	......	......	......	......	......	6 920	.00
	......	.18	......	......	......	......	......	......	......		
229	......	1 200	......	......	......	......	......	......	......	1 425	.00
	......	.25	......	......	......	......	......	......	......		

COMPRESSION TESTS.

FLAT-ENDED CHANNELS AND BEAMS.—No. 7.

No.	SHAPE.	SIZE.	LENGTH.		AREA.	ULTIMATE LBS. PER SQ. INCH.	$\frac{l}{r}$	REMARKS.
		In Inches.	*Ft.*	*In.*	*Sq. In.*			
230	Chan'l	$5 \times \frac{7}{32}$	8	$0\frac{1}{4}$	1.89	14 392	214	
231	"	"	5	$0\frac{5}{16}$	1.89	22 606	134	
232	"	"	6	$6\frac{1}{4}$	1.89	20 321	174	
233	"	"	3	$6\frac{1}{4}$	1.89	......	94	No failure at 50 000 lbs.
234	"	$6 \times \frac{1}{4}$	15	$0\frac{1}{2}$	3.23	6 200	270	
235	"	$8 \times \frac{3}{16}$	8	$0\frac{1}{4}$	2.99	......	160	No failure at 50 000 lbs.
236	"	$4 \times \frac{1}{4}$	8	0	1.92	13 177	192	
237	"	"	6	$6\frac{1}{8}$	1.91	21 466	156	
238	"	"	5	$0\frac{1}{4}$	1.91	26 316	120	
239	"	"	3	$6\frac{1}{4}$	1.91	......	85	No failure at 50 000 lbs.
240	"	$3 \times \frac{7}{32}$	8	$0\frac{1}{4}$	1.51	10 855	209	
241	"	"	6	$6\frac{1}{4}$	1.51	19 527	170	
242	"	"	5	$0\frac{1}{4}$	1.51	26 670	131	
243	"	"	3	$6\frac{1}{8}$	1.51	30 590	92	
244	"	$2 \times \frac{3}{16}$	8	$0\frac{1}{4}$	.80	6 626	310	
245	"	"	6	$6\frac{1}{4}$	.80	12 500	252	
246	"	"	5	$0\frac{5}{16}$	.80	10 580	195	
247	"	"	3	$6\frac{1}{8}$	.80	30 818	136	
248	Beam.	$6 \times \frac{1}{4}$	15	$0\frac{5}{8}$	4.15	11 400	279	
249	"	$5 \times \frac{5}{16}$	15	$0\frac{7}{16}$	3.35	8 960	300	
250	"	$5 \times \frac{7}{32}$	8	$0\frac{1}{4}$	2.92	....	160	No failure at 50 000 lbs.
251	"	$4 \times \frac{5}{32}$	8	$0\frac{5}{16}$	1.94	20 360	189	See Nos. 264 & 266.
252	"	"	6	$6\frac{1}{4}$	1.94	......	153	No fail're at 50 000 lb.
253	Chan'l	$4 \times \frac{1}{4}$	15	$0\frac{1}{2}$	2.17	5 740	361	
	Chan'l	6 inches.		6	2.33	42 290	10	Watertown test.
	"	"	1	$5\frac{6}{10}$	2.33	36 835	30	"
	"	"	1	$11\frac{9}{10}$	2.33	33 910	41	"
	"	"	4	0	2.33	28 140	83	"
	"	8 inches.		8	3.80	43 295	17	"
	"	"	1	$5\frac{9}{10}$	3.80	35 280	37	"
	"	"	1	$11\frac{9}{10}$	3.80	35 975	50	"
	"	"	2	$5\frac{9}{10}$	3.80	33 400	62	"
	"	"	4	0	3.80	30 620	100	"
	"	10 inches.		10	4.85	35 080	14	"
	"	"	1	$5\frac{9}{10}$	4.85	33 820	26	"
	"	"	1	$11\frac{9}{10}$	4.85	34 355	35	"
	"	"	2	$5\frac{9}{10}$	4.85	34 050	43	"
	"	"	4	0	4.85	34 080	70	"
	"	12 inches.	1	0	6.00	37 240	14	"
	"	"	1	$5\frac{8}{10}$	6.00	36 590	20	"
	"	"	1	$11\frac{9}{10}$	6.00	36 695	27	"
	"	"	2	$5\frac{9}{10}$	6.00	35 150	34	"
	"	"	4	0	6.00	36 040	55	"

LATERAL DEFLECTIONS OF FLAT-ENDED BEAMS AND CHANNELS.

THE UPPER FIGURES REPRESENT PRESSURES IN POUNDS.

THE FIGURES BELOW ARE THE CORRESPONDING DEFLECTIONS IN INCHES.

Number.										Ultimate Pressure.	Permanent Set.
230	500 .04	2 000 .05	4 000 .08	8 000 .13	12 000 .21	16 000 .28	20 000 .35	24 000 .47	27 000 .69	27 200	.18
231	500 .05	2 000 .05	6 000 .06	10 000 .07	14 000 .07	20 000 .08	30 000 .11	37 500 .15	42 500 .35	42 510	1.25
232	500 .02	3 000 .03	.... No fu	.... rther d	...... eflectio	.... n up to	30 000 .08	33 000 .11	36 000 .20	38 000	1.20
233	500 .04	5 000 .03	10 000 .04	15 000 .05	.... No d	.... eflectio	.... n and	.... no fail	.... ure.	....	.00
234	....	5 000 .06	10 000 .18	15 000 34	....	....	....	.. ..	....	20 000	.18
235	500 .02	10 000 .03	15 000 .06	20 000 .12	25 000 .22	30 000 .28	40 000 .35	45 000 .39	50 000 .50	No failure	.00
236	500 .06	2 000 .17	6 000 .39	10 000 .47	14 000 .57	18 000 .67	20 000 .73	22 000 .81	24 000 1.06	25 300	.83
237	500 .05	4 000 .04	8 000 .02	15 000 ·08	20 000 .09	25 000 .10	30 000 12	35 000 .15	40 000 .25	41 000	.27
238	500 .03	10 000 .03	20 000 .05	25 000 .06	30 000 .07	35 000 .08	40 000 .10	45 000 .12	50 000 .18	50 000	1.38
239	500 .02	10 000 .03	25 000 03	40 000 .04	45 000 .05	50 000 .08	....	... ...	....	No failure	.00
240	500 .07	2 000 .09	4 000 .13	6 000 .19	8 000 .26	10 000 .37	12 000 .46	14 000 .61	16 000 .84	16 500	.18
241	500 .02	2 000 .03	6 000 .09	10 000 12	14 000 .14	18 000 .16	22 000 .20	26 000 .27	28 000 .38	28 910	1.62
242	500 .00	5 000 .02	10 000 .03	15 000 .03	20 000 .03	25 000 .03	30 000 .04	35 000 .06	37 500 .09	40 000	1.37
243	500 .04	.... No	.... deflect	.... ion up	.... to	42 000 .06	45 000 .09	....	....	46 475	.60
244	500 .04	1 000 .10	1 500 .18	2 000 .22	3 000 .31	3 500 .41	4 000 .50	4 500 .60	5 000 .82	5 420	.26
245	500 .04	2 000 .09	4 000 .17	5 000 ,20	6 000 .22	7 000 .27	8 000 .33	9 000 .43	10 000 .75	10 010	.21
246	500 .03	2 000 .10	3 000 .22	4 000 .26	5 000 .28	6 000 .31	7 000 34	8 000 .45	....	8 420	.29
247	500 .03	7 000 .03	10 000 .05	14 000 .06	16 000 .07	18 000 .08	20 000 .09	22 000 .11	24 000 .15	24 500	....
248	....	10 000 .11	20 000 .25	30 000 .25	35 000 .12	45 000 .37	....	....	....	47 220	.62
249	....	5 000 .18	10 000 .18	15 000 22	20 000 .25	25 000 .44	30 000 1.12	....	....	30 025	.25
250	500 .03	5 000 .11	15 000 .18	25 000 .21	30 000 .23	35 000 .25	40 000 .27	45 000 .30	50 000 .36	No failure	.00
251	500 .05	5 000 .05	10 000 .06	15 000 .08	20 000 .10	25 000 .12	30 000 .16	35 000 .22	39 000 .35	39 490	.98
252	500 .04	5 000 .05	20 000 .03	40 000 .05	45 000 .07	50 000 .15	....	....	....	No failure	.00
253	....	5 000 .18	10 000 .56	....	....	....	....	....	....	12 450	.00

COMPRESSION TESTS

Of Welded Tubes, Flat-ended.—No. 8.

No.	Outer Diam'tr.	Length.	Area.	Ultimate Lbs. per Sq. Inch.	$\frac{l}{r}$	Remarks.
		Ft. In.	*Sq. In.*			
270	2.87 inches.	8 0	1.72	....	101	No failure at 50 000 lbs.
271	" "	8 0	1.64	20 122	101	Not same Tube as last.
272	" "	8 0	1.64	17 614	101	Same Tube as last.
273	" "	15 0	1.64	13 810	190	
274	2.37 "	15 0	1.04	16 680	221	
275	" "	7 11¾	1.08	27 780	123	
276	" "	6 6	1.08	31 018	100	
277	" "	4 10	1.08	37 103	75	
278	" "	3 4½	1.08	36 239	52	
	Welded	Tubes,	with	flanged	ends.	
		Ft. In.	*Sq. In.*			
279	2.87 inches.	15 0	1.64	19 000	189	
280	2.37 "	15 0	1.04	15 400	221	
281	" "	8 0	1.08	24 780	121	
282	" "	6 6	1.08	30 700	98	
283	" "	5 0	1.08	32 710	75	
284	" "	3 5	1.08	38 200	52	
	Welded	Tubes,	with	hinged	ends.	
		Ft. In.	*Sq. In.*			
285	3.5 inches.	15 0	2.12	....	153	On a 2″ pin. No failure at 50 000 lbs.
286	Same Tube.	15 0	2.12	13 940	153	On 2″ balls and sockets.
287	" "	15 0	2.12	11 410	153	" " " " plates.
288	2.87 inches.	15 0	1.64	10 840	194	2″ pins.
289	Same Tube.	15 0	1.64	8 840	194	2″ balls and sockets.
290	" "	15 0	1.64	7 650	194	2″ " " plates.
291	2.37 inches.	15 0	1.04	14 420	224	2″ pins.
292	Same Tube.	15 0	1.04	11 300	224	2″ balls and sockets.
293	" "	15 0	1.04	5 000	224	Round ends.
294	2.87 inches.	8 4	1.72	25 580	105	2″ balls and sockets.
295	2.37 "	8 4	1.07	23 364	128	2″ " " "
296	" "	6 8	1.15	28 260	103	2″ " " "
297	" "	5 2	1 07	34 112	80	2″ " " "
298	" "	3 8	1.07	38 785	57	2″ " " "
299	1.31 "	8 3	.46	5 857	247	1″ " " "
300	3.5 "	15 0	2.12	18 880	153	2″ pin .10 in. out of centre.

LATERAL DEFLECTIONS OF WELDED TUBES, FLAT-ENDED.

The upper figures represent pressures in pounds.

The figures below are the corresponding deflections in inches.

Number.										Ultimate Pressure.	Permanent Set.
270	700 .08	5 000 .09	10 000 .10	15 000 .12	20 000 .13	30 000 .14	40 000 .15	45 000 .18	50 000 .22	No failure	......
271	1 000 .09	10 000 .10	15 000 .14	20 000 .15	25 000 .19	30 000 .21	33 000 .42	......	......	33 020	......
272	1 000 .05	5 000 .10	10 000 .17	15 000 .21	20 000 .25	25 000 .28	30 000 .49	......	......	31 000	.77
273	500 .00	......	10 000 .00	20 000 1.56	......	......	......	......	......	22 725	......
274	......	......	10 000 .18	......	......	......	......	......	......	17 350	......
275	......	1 000 .03	5 000 .09	10 000 .11	15 000 .14	20 000 .15	25 000 .20	30 000 .53	......	30 025	.28
276	500 .03	5 000 .00	10 000 .05	15 000 .06	20 000 .08	25 000 .10	30 000 .14	......	......	33 520	.28
277	500 .02	5 000 .03	10 000 .03	15 000 .03	20 000 .03	25 000 .00	30 000 .02	35 000 .03	......	39 700	.30
278	500 .01	5 000 .02	10 000 .03	15 000 .03	20 000 .03	25 000 .04	30 000 .04	35 000 .04	......	39 525	.10
				Flanged Ends.							
279	......	10 000 .15	20 000 .28	30 000 .75	......	......	......	......	......	31 175	......
280	......	10 000 .50	......	......	......	......	......	......	......	15 990	......
281	500 .06	5 000 .10	10 000 .12	15 000 .13	20 000 .15	25 000 .17	......	......	......	28 030	.98
282	500 .05	5 000 .05	10 000 .05	15 000 .06	20 000 06	25 000 .07	30 000 .08	35 000 29	......	35 025	.14
283	500 .03	5 000 .06	10 000 .07	15 000 .08	20 000 .09	25 000 .09	30 000 .10	......	......	34 995	.38
284	500 .02	5 000 .03	10 000 .03	20 000 .04	25 000 .04	30 000 .04	35 000 .04	40 000 .10	......	40 485	.32
				Hinged Ends.							
285	......	10 000 .15	20 000 .18	30 000 .25	40 000 .28	50 000	......	......	......	No failure	......
286	......	10 000 .22	20 000 .53	......	......	......	......	......	......	29 550	.00
287	......	10 000 .12	20 000 .43	......	......	......	......	......	......	24 210	.00
288	......	10 000 ,70	......	......	......	......	......	......	......	17 775	.00
289	......	10 000 .22	......	......	......	......	......	......	......	14 510	.00
290	......	10 000 .14	......	......	......	......	......	......	......	12 550	.00
291	......	5 000 .06	10 000 .18	15 000	...... Held	...... 15 000	...... for a	...... few se	...... conds.	15 000	.00
292	......	5 000 .05	10 000 .12	......	......	......	......	......	......	11 750	.00
293	......	4 000 .25	......	......	......	......	......	......	......	5 190	.00
294	500 .02	10 000 .02	15 000 .03	20 000 .04	25 000 .05	30 000 .06	35 000 .10	40 000 .14	......	43 990	.55
295	500 .04	5 000 .05	10 000 .07	15 000 .11	20 000 .14	25 000	......	......	......	25 000	.64
296	500 .01	5 000 .02	10 000 .04	15 000 .06	20 000 .08	25 000 .09	30 000 .12	......	......	32 495	.62
297	500 .05	5 000 .06	10 000 .07	15 000 .07	20 000 .09	25 000 .09	30 000 .10	35 000 .15	......	36 500	.05
298	500 .02	25 000 .02	35 000 .03	40 000 .05	......	......	......	......	......	41 510	.63
299	500 .13	1 000 .18	2 000 ,25	......	......	......	......	......	......	2 695	.00
300	......	10 000 .19	20 000 .28	30 000 .37	40 000 .44	......	......	......	......	40 020	......

COMPRESSION TESTS.

HINGED-ENDED CHANNELS AND BEAMS.

(See Diagram No. 4.) Plate

No.	SHAPE.	SIZE.	LENGTH.	AREA.	ULTIMATE LBS. PER SQ INCH.	$\frac{l}{r}$	REMARKS.
		In Inches.	*Ft. Ins.*	*Sq. In.*			
260	Chan'l	8 x $\frac{3}{16}$	8 4$\frac{1}{4}$	3.05	11 738	167	2″ balls and sockets.
261	Beam	5 x $\frac{7}{32}$	8 4$\frac{1}{4}$	2.98	11 200	167	2″ " "
262	Chan'l	5 x $\frac{7}{32}$	4 0$\frac{1}{2}$	1.87	11 550	108	2″ " "
263	"	4 x $\frac{1}{4}$	4 0$\frac{1}{4}$	1.90	18 421	97	2″ " "
264	Beam	4 x $\frac{5}{32}$	6 10$\frac{1}{4}$	1.94	....	161	2″ " " [lbs. No failure at 50 000
265	Chan'l	6 x $\frac{1}{4}$	15 3$\frac{1}{2}$	4.15	3 700	273	1″ balls and sockets.
266	Beam	4 x $\frac{5}{32}$	6 10$\frac{1}{4}$	1.94	12 113	161	Round-ended 2″ balls.
267	"	6 x $\frac{1}{4}$	15 4$\frac{1}{2}$	4.15	6 020	273	2″ pins.
268	"	Same bar.	15 4$\frac{1}{2}$	4.15	9 050	273	2″ "
269	Chan'l	4 x $\frac{1}{4}$	15 4$\frac{1}{2}$	2.17	5 880	364	2″ "

Numbers 264, 266, are hinged and round-ended retests of No. 252, which did not fail flat-ended with 50 000 lbs.

LATERAL DEFLECTIONS OF HINGED-ENDED CHANNELS AND BEAMS.

THE UPPER FIGURES REPRESENT PRESSURES IN POUNDS.

THE FIGURES BELOW ARE THE CORRESPONDING DEFLECTIONS IN INCHES.

Number.										Ultimate Pressure.	Permanent Set.
260	500 .04	5 000 .06	10 000 .07	15 000 .07	20 000 .07	25 000 .08	30 000 .11	35 000 .45	....	35 820	.95
261	500 .03	5 000 .04	10 000 .05	15 000 .07	20 000 .11	25 000 .20	30 000 .36	....	....	33 400	.82
262	500 .05	5 000 .08	10 000 .11	15 000 .16	20 000 .22	....	....	....	....	21 610	.52
263	500 .02	5 000 .02	10 000 .03	15 000 .04	20 000 .05	25 000 .06	30 000 .08	....	....	35 000	.48
264	500 .02	.... No d	.... eflectio	.... n up to	15 000 .03	30 000 .02	45 000 .05	50 000 .07	....	No failure	.00
265	....	5 000 .03	10 000 .12	15 000 1.09	....	....	....	....	....	15 350	.00
266	500 .02	.... No d	.... eflectio	.... n up	.... to 20	 000	20 000 .03	....	....	23 500	.63
267	....	10 000 .03	20 000 .16	....	....	....	....	....	....	25 000	.00
268	....	10 000 .09	20 000 .12	30 000 .16	....	....	....	....	....	37 550	.00
269	....	5 000 .00	10 000 .06	....	....	....	....	....	....	12 750	.00

The following examples illustrate the wide range of resistance produced in the bars by a change in their end conditions, and the rapid fall of resistance that occurred when but a trifling deviation from the true centre existed.

It will be understood that in all pin-ended tests the pins were placed at right angles to the least radius of gyration of the strut. Also, when bars were moved on their hinged ends, the movement was made in the direction of the least radius, unless otherwise stated, and in that direction which tended to reverse the deflection of the previous experiment. The number of the experiment given on the left corresponds with the numbers on tables and diagrams, where the particulars of the test can be found.

Two bars of angle iron, $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{9}{32}$ inches, 5 feet $4\frac{1}{16}$ inches long, were cut from the same original bar, and adjusted in the testing machine, as near as possible, with the centres of gravity of section in line with centres of the balls which capped both ends.

Number of Experiment.		Ultimate Load in Pounds.
91	With 2-inch balls and sockets, failed with..............	36 500
92	" 1 " " "	24 010
	These bars were then straightened cold and changed on the balls, centres precisely as before.	
91	With 1-inch balls and sockets, failed with..............	17 500
92	" 2 " " "	36 500

Angle $2 \times 2 \times \frac{5}{16}$ inches, 8 feet $3\frac{1}{8}$ inches long.

82	First test with 1-inch balls and sockets, failed with......	4 500
83	Second test, same balls, moved .08 inch, "	8 100

Tee, $2\frac{1}{2} \times 2\frac{1}{2} \times 3$ feet, $6\frac{1}{8}$ inches long.

54	First test, flat-ended, no failure with..................	50 000
144	Second test with 2-inch balls and sockets, failed with....	48 500
—	Third test, straightened hot, and placed $\frac{1}{8}$ inch out of centre, in the direction of the stem, failed with........	30 620
147	Another bar, same dimensions, tested with 2-inch balls and sockets, failed in a few seconds..................	50 000

Number of Experiment.		Ultimate Load in Pounds.
	Angle $3 \times 3 \times \frac{3}{8}$ inches, 8 feet $\frac{1}{4}$ inch long, tested, straightened and retested in the succession given.	
147	First test with 2-inch balls and sockets, apparently central	19 400
80	Second test with 2-inch balls and sockets, moved .06 inch	27 850
170	Third test with fixed ends................................	39 700
	Angle $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$ inches, 8 feet long, tested, straightened, and retested successively.	
—	First test with 2-inch balls and sockets, .08 inch out of centre..	12 100
81	Second test with 2-inch balls and sockets and moved .08 in.	24 600
171	Third test with fixed ends................................	36 790
	Angle $1\frac{1}{4} \times 1\frac{1}{4} \times \frac{1}{4}$ inches, 8 feet long. No straightening done.	
84	First test with 1-inch balls and sockets..................	2 800
—	Second test, same balls, moved .10 inch................	1 850

In the following experiments, as the bars fully recovered their original condition, after the application of each ultimate load (excepting the fixed-ended tests, which were made last), the loads were applied continuously, without taking the bars from the machine.

Number of Experiment.		Ultimate Load in Pounds.
167	Tee, 3×3 inches, 15 feet $1\frac{3}{4}$ inches long, tested with 2-inch pins...	23 500
—	Pin then turned at right angles to stem, with same pins..	21 400
	In both experiments the bar failed in the direction of the flange. No rotation on the pin at second test.	
166	Tee, 4×4 inches, 15 feet $\frac{5}{8}$ inches long, on 2-inch pins, no failure...	50 000
—	Second test, the pins moved .10 inch, failed...........	27 750
—	Third " " " .20 " "	18 150
73	Fourth " pins removed, tested flat-ended, no failure.	50 000
	Uneven angle, $4 \times 3 \times \frac{15}{32}$ inches, 15 feet $5\frac{3}{8}$ inches long.	
117	First test with 2-inch balls and sockets	21 500
—	Second " 1 " "	10 790
—	Third " 2-inch pins	14 675

Number of Experiment.		Ultimate Load in Pounds.
126	Fourth test with 2-inch pins, moved .06 inch............	27 020
31	Fifth test, pins removed, flat-ended....................	22 600
—	Sixth " had now some permanent curvature, fixed-ended..	17 620
	Angle, $2\frac{3}{4}$ x $2\frac{3}{4}$ x $\frac{3}{8}$ inches, 10 feet $6\frac{1}{4}$ inches long.	
118	First test with 2-inch balls and sockets, apparently central...	16 700
—	Second test with same ends, moved .06 inch............	26 450
30	Third test, balls removed, flat ends....................	22 250
	Angle, $3\frac{1}{2}$ x $3\frac{1}{2}$ x $\frac{3}{8}$ inches, 10 feet $6\frac{1}{4}$ inches long.	
—	First test with 2-inch balls and sockets................	20 150
119	Second test with same ends, moved .07 inch............	38 175
29	Third test, balls removed, flat ends....................	39 425
	Angle, 2 x 2 x $\frac{5}{16}$ inches, 15 feet $\frac{3}{16}$ inch long.	
229	First test with 1-inch balls and plates, round ends.	1 425
123	Second " 1 " " sockets, hinged ends.....	1 550
122	Third " 2 " " " " "	1 900
36	Fourth " balls removed, flat ends................	2 910
195	Fifth " clamps applied, fixed ends..............	5 150
	Angle, 3 x 3 x $\frac{7}{16}$ inch, 15 feet $\frac{1}{4}$ inch long.	
228	First test with 1-inch balls and plates, round ends.......	6 920
227	Second " 2 " " " " "	7 575
121	Third " 1 " " sockets, hinged ends.....	7 400
—	Fourth " 2 " " " " "	14 000
120	Fifth " 2 " pins, hinged ends................	14 925
33	Sixth " ends removed, flat ends................	15 400
191	Seventh " clamps applied, fixed ends..............	21 475
	I Beam, 6 x $\frac{1}{4}$ inches, 15 feet $\frac{1}{2}$ inch long.	
265	First test with 1-inch balls and sockets, hinged ends	15 350
267	Second " 2 " " " apparently central, hinged ends................................	25 000
—	Third test with same balls, moved .10 inch apparently out of centre..	37 550

Number of Experiment.		Ultimate Load in Pounds.
267	Fourth test with same balls, moved .20 inch in same direction	13 650
—	Fifth test with same balls, moved .30 inch in same direction	12 025
—	Sixth test with same balls, moved .40 inch in same direction	11 275
—	Seventh test with same balls, moved .50 or ½ inch out of centre	11 200
248	Eighth test, balls removed, flat ends	47 220

The following tests of tubes were also made continuously, without being taken from the machine, and in the succession given. The sizes are inside diameters.

Tube, 2-inch diameter, 15 feet long.

Number of Experiment.		Ultimate Load in Pounds.
293	First test with 2-inch balls and plates, round ends	5 190
292	Second " 2 " " sockets, hinged ends	11 750
291	Third " 2 " pins, hinged ends	15 000
274	Fourth test, hinged ends removed, flat ends	17 350
280	Fifth test, flanges put on, flanged ends	15 990

The above tube was slightly injured with the fourth test.

Tube, 2½ inches in diameter, 15 feet long.

290	First test with 2-inch balls and plates, round ends	12 550
289	Second " 2 " " sockets, hinged ends	14 510
288	Third " 2 " pins, hinged ends	17 775
273	Fourth test, balls removed, flat ends	22 725
279	Fifth " flanges put on, flanged ends	31 175

Tube, 3 inches diameter, 15 feet long.

287	First test, 2-inch balls and plates, round ends	24 210
286	Second " 2 " " sockets, hinged ends	29 550
285	Third " 2 " pins. No failure with	50 000
300	Fourth " same pins, moved .10 inch	40 020

The records of the second test are not complete; the tube may have been placed out of centre designedly.

No. 9.

AVERAGE RESULTS OF TESTS OF STRUTS.

Ultimate in Pounds per Square Inch.

Length divided by Least Rad. of Gyr'n.	Flat-ended Angles.	Hinged-ended Angles.	Fixed-ended Angles.	Flat-ended Tees.	Hinged-ended Tees.	Round-ended Tees.	Flat-ended Channels and Beams.
20	49 000	45 000	45 000	49 000	47 000	44 000	38 000
40	40 000	40 000	38 000	42 000	41 000	36 500	35 000
60	35 000	36 000	34 000	38 000	36 000	30 500	34 000
80	32 000	32 000	32 000	35 000	31 000	25 000	31 500
100	29 000	29 000	30 000	31 500	27 000	20 500	29 000
120	26 000	26 000	28 000	27 000	22 500	16 500	26 000
140	23 500	22 000	25 500	23 000	18 500	12 800	24 000
160	21 000	17 000	23 000	20 000	15 500	9 500	21 000
180	19 000	13 000	20 000	17 000	12 500	7 500	18 000
200	16 500	11 000	17 500	14 000	10 500	6 000	15 000
220	14 000	9 000	15 000	12 000	8 500	5 000	12 500
240	12 000	8 000	13 000	11 000	7 000	4 300	11 000
260	10 500	7 000	11 000	10 000	6 000	3 800	10 000
280	9 000	6 000	10 000	8 500	5 500	3 200	9 000
300	7 500	5 000	9 000	7 000	5 000	2 800	7 500
320	6 000	4 500	8 000	5 500	4 500	2 500	6 000
340	4 800	4 000	7 000	4 500	4 000	2 100	5 000
360	3 800	3 500	6 500	4 000	3 500	1 900	4 000
380	3 200	3 000	5 800	3 500	3 000	1 700	
400	2 900	2 500	5 200	3 000	2 500	1 500	
420	2 500	2 300	4 800	2 500	2 200	1 300	
440	2 200	2 100	4 300				
460	2 000	1 900	3 800				
480	1 900	1 700					

No. 10.

COMBINED AVERAGE RESULTS OF TESTS OF STRUTS.

ULTIMATE IN POUNDS PER SQUARE INCH.

Length divided by Least Rad. of Gyration.	Flat Ends.	Fixed Ends.	Hinged Ends.	Round Ends.
20	46 000	46 000	46 000	44 000
40	40 000	40 000	40 000	36 500
60	36 000	36 000	36 000	30 500
80	32 000	32 000	31 500	25 000
100	29 800	30 000	28 000	20 500
120	26 300	28 000	24 300	16 500
140	23 500	25 500	21 000	12 800
160	20 000	23 000	16 500	9 500
180	16 800	20 000	12 800	7 500
200	14 500	17 500	10 800	6 000
220	12 700	15 000	8 800	5 000
240	11 200	13 000	7 500	4 300
260	9 800	11 000	6 500	3 800
280	8 500	10 000	5 700	3 200
300	7 200	9 000	5 000	2 800
320	6 000	8 000	4 500	2 500
340	5 100	7 000	4 000	2 100
360	4 300	6 500	3 500	1 900
380	3 500	5 800	3 000	1 700
400	3 000	5 200	2 500	1 500
420	2 500	4 800	2 300	1 300
440	2 200	4 300	2 100	
460	2 000	3 800	1 900	
480	1 900	......	1 800	

The experiments do not justify the statement that the short fixed-ended struts are as strong as similar lengths of flat or hinged-ended.

This equality is hypothetical, and based on the assumption, previously stated, that the effective lengths of the fixed-ended struts were greater than the lengths recorded.

CONCLUSIONS.

The following general conclusions may be derived from the experiments:

When struts are short, say $\frac{l}{r}$ below 20, there will be no practical difference in the strength of the four classes, so long as reasonable care is taken to keep the centre of pressure in the centre of the strut.

Hinged-ended struts vary all the way from round-ended up to flat-ended in strength. If the hinge pins are of insignificant diameter, and imperfectly centred, the strut ought then to be classified as round-ended.

On the contrary, if the pins are of substantial diameter, well fitted, and exactly centred with the axis of greatest resistance of the strut, the hinged-ended will be fully as strong as the flat-ended strut; but considering the impracticability of maintaining this rigid accuracy, the average hinged struts, as compared with flat-ended, will fall in strength as the length is increased, until $\frac{l}{r}$ becomes about 250, when they will average one-third less resistance than flat-ended. From this point they will gain in comparative resistance until $\frac{l}{r}$ becomes about 500, when both classes will be practically equal.

Fixed-ended struts gradually gain in comparative strength, from the least lengths upward, until $\frac{l}{r}$ becomes about 500, when they will be twice as strong as either the flat-ended or hinged-ended.

Round-ended struts continually lose in comparative strength. When $\frac{l}{r}$ is about 160 they will be about half as strong as flat-ended, and when $\frac{l}{r}$ becomes about 450 they will have about half the strength of hinged-ended struts.

Quality of the Iron.

The quality of iron experimented upon was such as would be used to conform to the bridge specifications of the Pennsylvania, or New York, Lake Erie & Western R. R. Companies, and would in tension average as follows per square inch:

Breaking Strain.	Elastic Limit.
49 000 lbs.	32 000 lbs.

18 per cent. elongation in 8 inches.

The same iron exhibited the following resistance to direct compression, being the average of several tests of small sections, 12 inches long, secured in such a manner as to prevent lateral flexure. With pressures varying from 26 000 to 32 000 lbs. per square inch, the elastic limit was reached; that is, the point where the reduction of length increased

in a greater ratio than the pressure increased. The higher values were obtained from specimens whose rolled sections were less than one square inch; the lower values, from strips cut from angles whose rolled section was about 4 square inches.

With 50 000 lbs. pressure per square inch, a permanent reduction of length of 2½ per cent. was produced.

With 75 000 lbs. a reduction of 6 per cent., and with 100 000 lbs. per square inch the permanent reduction of length averaged 8 per cent.

The diagrams referred to in this paper are shown on Plates XXVI, XXVII, XXVIII and XXIX.

APPENDIX.

COMPARATIVE ELASTICITY OF WROUGHT-IRON IN TENSION AND IN COMPRESSION.

It is difficult to ascertain the elasticity of the metals under compression, owing to the specimen operated upon bending under the crushing strain when the ratio of length to diameter exceeds certain limits.

It is necessary to secure the specimen laterally, so that it cannot bend, but not use such constraint as will offer any resistance to its free longitudinal movement, or the enlargement of its sectional area. Of several methods tried by the writer, the one hereafter described gave the best results.

The specimen to be operated on is inserted in a tube, in which it has abundant lateral freedom. The tube is made a little longer than the specimen, say one or two inches, and has a plug neatly fitted in each end, the plugs projecting past the ends of the tube, so that as the specimen is shortened by the crushing force the plates of the testing machine will not touch the tube.

A few set screws are passed through the cylindrical shell of the tube, at any convenient points, by means of which the specimen can be held in position while being adjusted in the machine. The space inside the tube and around the specimen is filled with fine dry sand, and the testing machine brought to act on the specimen through the plugs, which close the ends of the tube. As the pressure increases the set screws are gradually relaxed, so that the sand sustains no pressure, except that exerted by the specimen in the effort to bend laterally under the crushing strain. After a few trials the operator will learn how to best obtain the desired result. The following tests under compression were obtained by the foregoing method.

Measurements were taken with a callipers by the sense of touch, and read on a measuring machine to the nearest $\frac{1}{1000}$th of an inch.

TWO PIECES OF ¾-INCH SQUARE IRON.

CUT FROM SAME BAR.

Area of Section 0.556 Square Inches.

PRESSURES IN POUNDS. CHANGE OF LENGTH IN INCHES.

TENSILE TEST, Measured on a Length of 12 inches.				COMPRESSIVE TEST, Measured on a Length of 11.96 inches.			
Total Pressure.	Pressure per Square Inch.	Elongations.		Total Pressure.	Pressure per Square Inch.	Reduction of Length.	
		Load on.	Load off.			Load on.	Load off.
2 780	5 000	.002	.000	2 780	5 000	.002	.000
5 560	10 000	.0045	.000	5 560	10 000	.0035	.000
8 340	15 000	.007	.000	8 340	15 000	.005	.000
11 120	20 000	.0085	.000	11 120	20 000	.006	.000
12 232	22 000	.010	.000	12 232	22 000	.007	.000
13 344	24 000	.0105	.000	13 344	24 000	.008	.000
14 456	26 000	.0115	.000	14 456	26 000	.009	.000
15 568	28 000	.012	.000	15 568	28 000	.0095	.000
16 680	30 000	.013	.000	16 680	30 000	.010	.000
17 792	32 000	.0135	.000	17 792	32 000	.011	.000
18 904	34 000	.0145	.000	18 904	34 000	.020	.0035
20 016	36 000	.0155	.001	20 016	36 000	.023	.0045
21 128	38 000	.1715	.1495	21 128	38 000	.027	.010
22 240	40 000	.3835	.3605	22 240	40 000	.107	.089
27 800	50 000	1.326	1.2945	27 800	50 000	.272	.246
29 925	53 821	3.093	......	33 360	60 000	.4645	.4355
				38 920	70 000	.671	.639
Specimen broke with 53 821 lbs. per square inch.				44 480	80 000	.845	.8145
Stretch 3.09 inch in 12 inches.				50 040	90 000	1.074	1.042
" 2.187 " 8 "							
" 27.33 per cent. in 8 inches.							
Fractured area 0.3364 square inches.							

TWO PIECES OF ¾-INCH ROUND IRON.

Cut from Same Bar.

Area of Section 0.449 Square Inches.

Pressures in Pounds. Change of Length in Inches.

TENSILE TEST,

Measured on a Length of 12 inches.

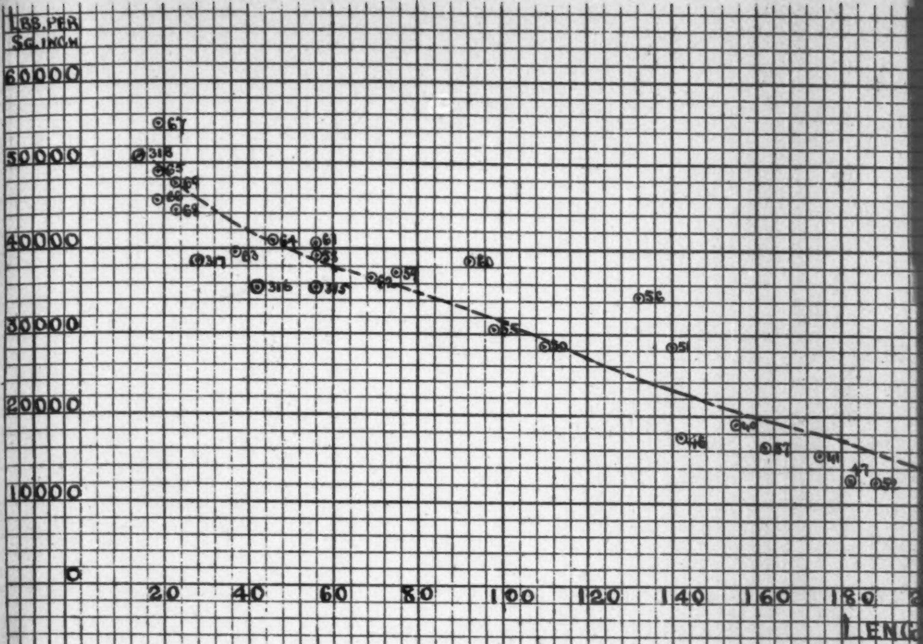
Total Pressure.	Pressure per Square Inch.	Elongations. Load on.	Elongations. Load off.
2 245	5 000	.001	.000
4 490	10 000	.004	.000
6 735	15 000	.005	.000
8 980	20 000	,008	.000
9 878	22 000	.009	.000
10 776	24 000	.010	.000
11 674	26 000	.0105	.000
12 572	28 000	.011	.000
13 470	30 000	.013	.000
14 368	32 000	.014	.000
15 266	34 000	.015	.002
16 164	36 000	.022	007
17 062	38 000	.416	.3995
17 960	40 000	.5445	.523
22 450	50 000	1.740	1.707
23 175	51 600	2.468	....

Specimen broke with 51 600 lbs. per square inch.
Stretch in 12 inches 2.468 inch.
" 8 " 1.812 "
" 8 " 22.65 per cent.
Fractured area 0.297 square inches.

COMPRESSIVE TEST,

Measured on a Length of 12.048 inches.

Total Pressure.	Pressure per Square Inch.	Reduction of Length. Load on.	Reduction of Length. Load off.
2 245	5 000	.002	.000
4 490	10 000	.005	.000
6 735	15 000	.007	.000
8 980	20 000	.010	.000
9 878	22 000	.011	.001
10 776	24 000	.012	.002
11 674	26 000	.013	.003
12 572	28 000	.015	.0045
13 470	30 000	.0215	.0065
14 368	32 000	.0225	.007
15 266	34 000	.0275	.009
16 164	36 000	.040	.019
17 062	38 000	.052	.036
17 960	40 000	.133	.1145
22 450	50 000	.3045	.283
26 940	60 000	.4275	.402
31 430	70 000	.5465	.521
35 920	80 000	.663	.635
40 410	90 000	.773	.742
44 900	100 000	.896	.862



LBS. PER SQ. INCH
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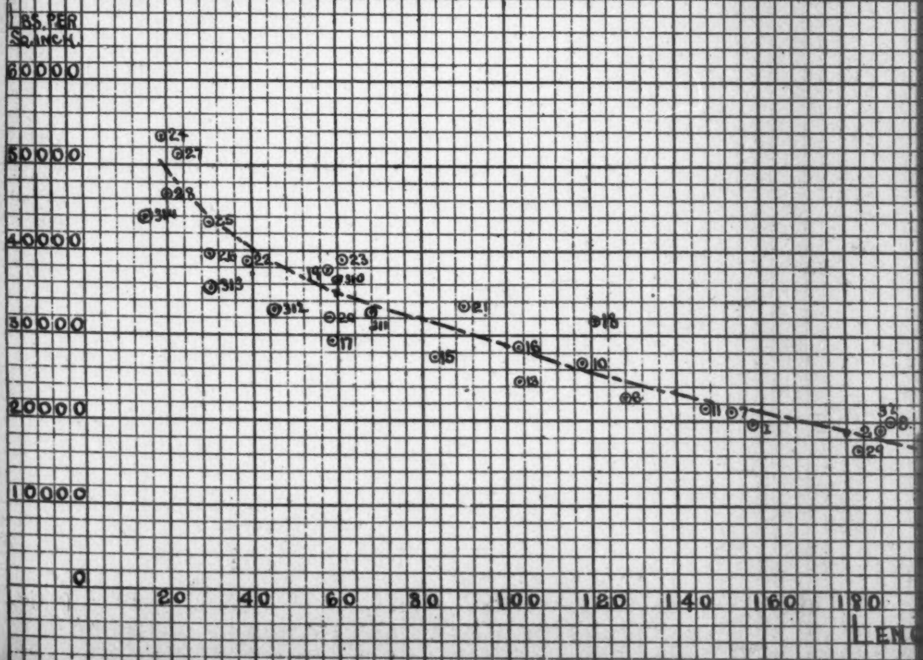
50000
40000
30000
20000
10000
0
20
40
60
80
100
120
140
160
180
LENG



LBS. PER SQ. INCH.
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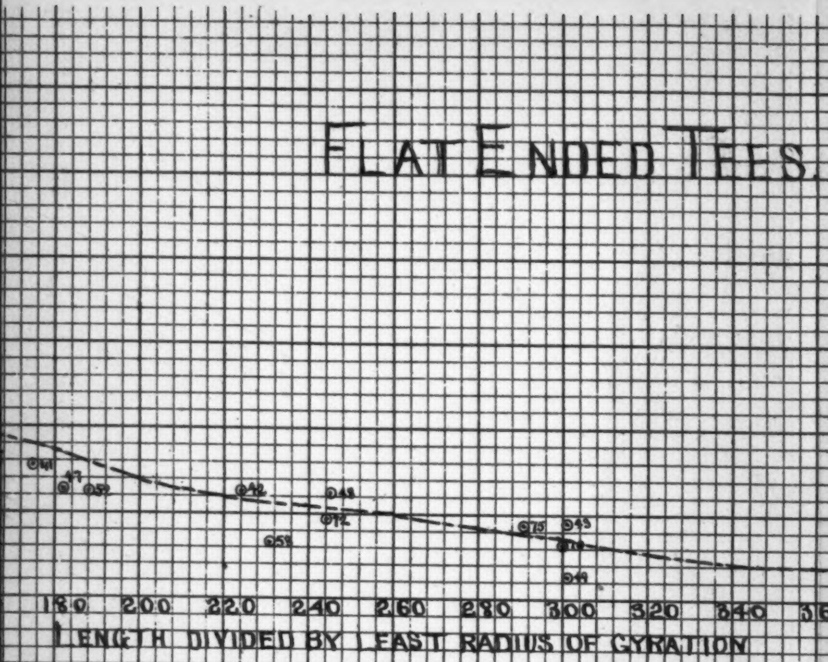
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LENGTH DIVIDED BY LEAST RADIUS OF GYRATION

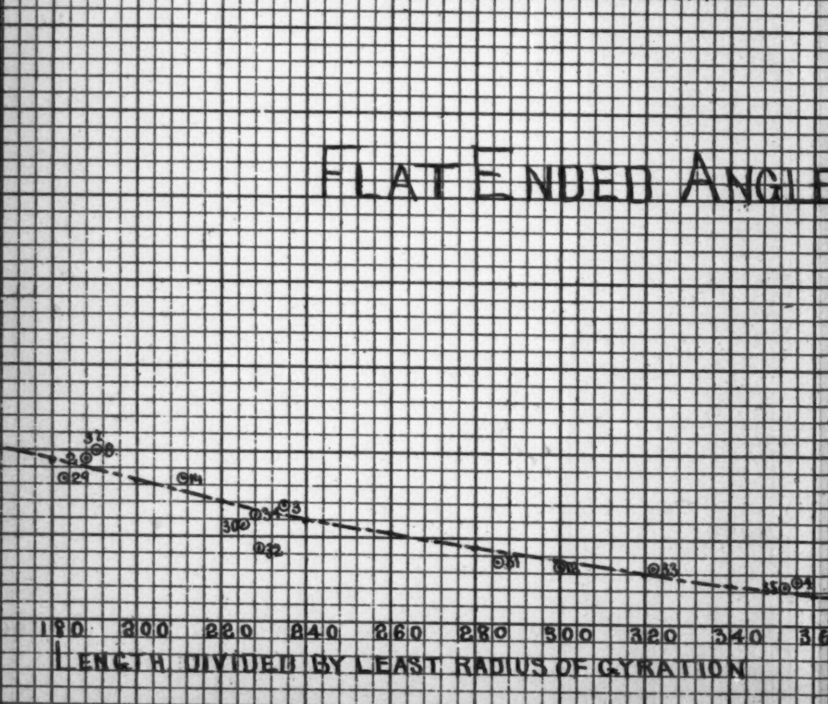
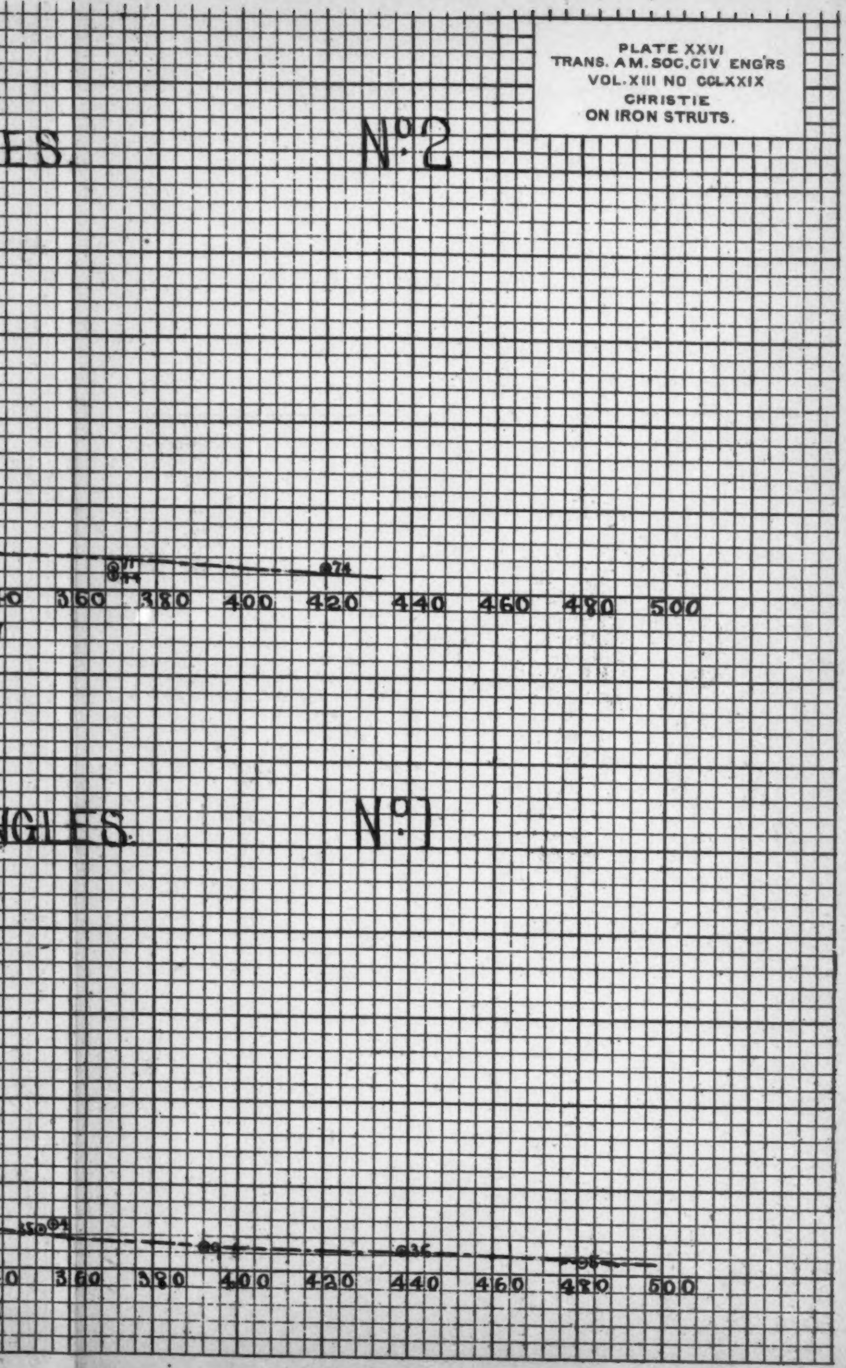
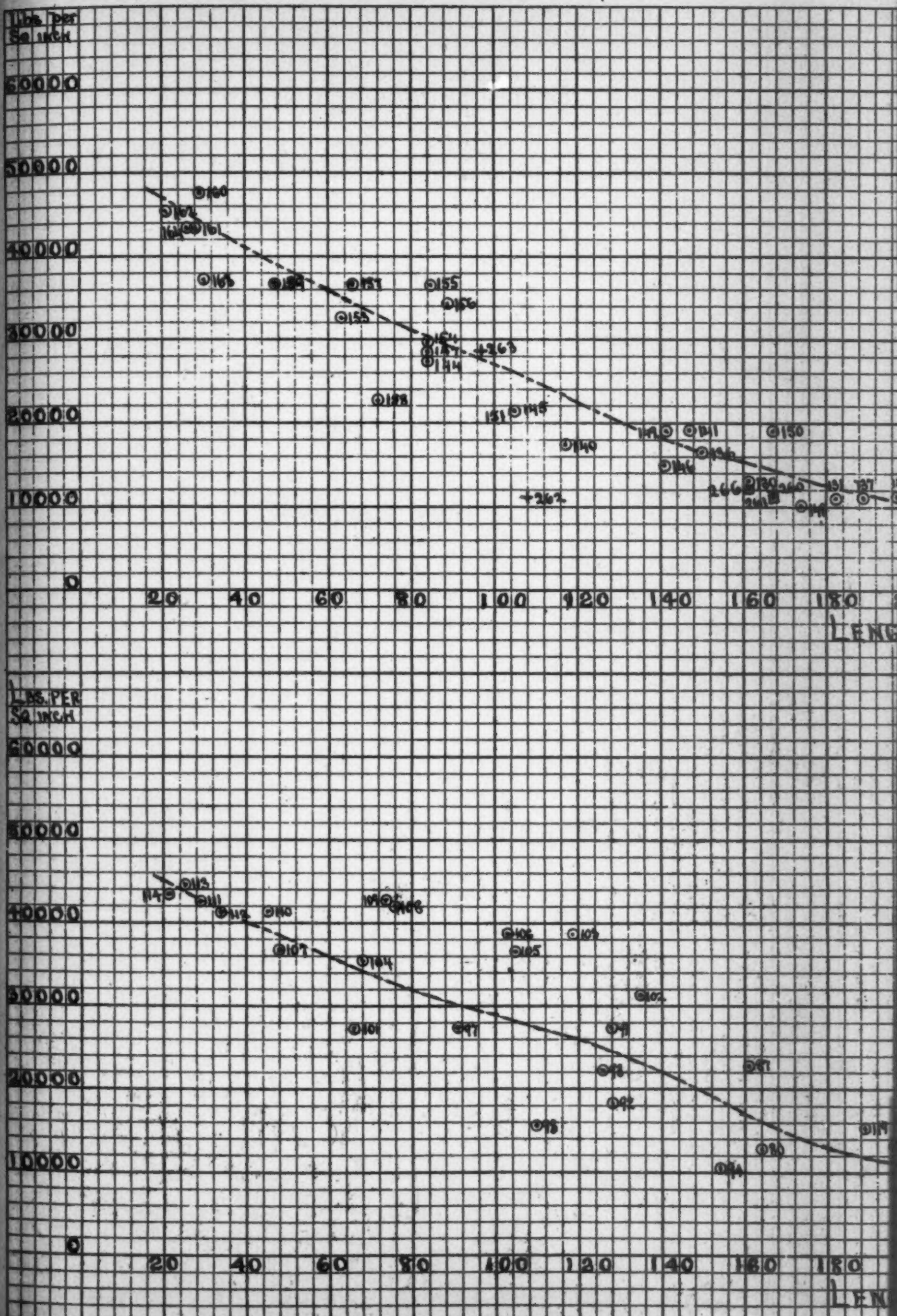
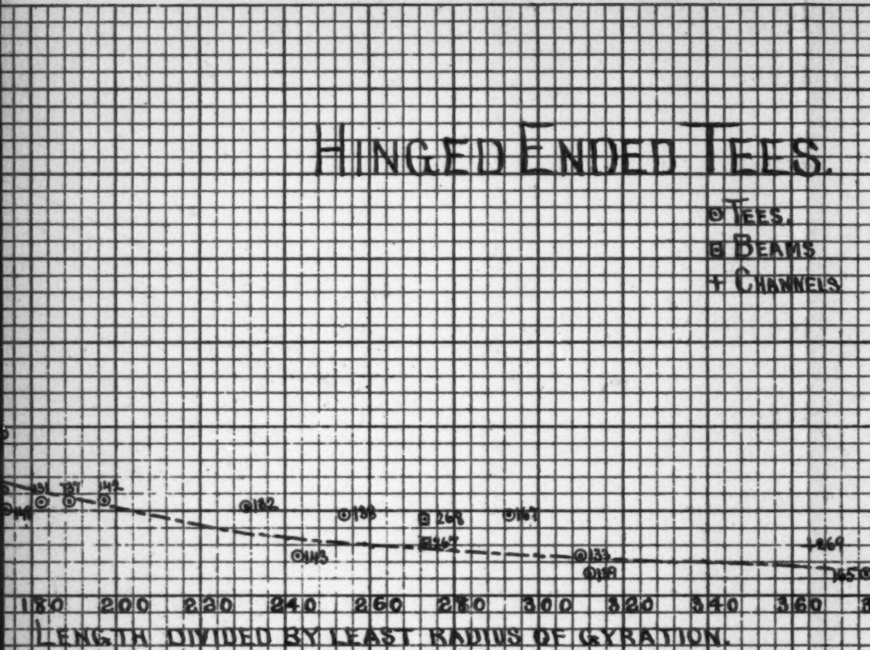

FLAT ENDED ANGLE
180 200 220 240 260 280 300 320 340
LENGTH DIVIDED BY LEAST RADIUS OF GYRATION

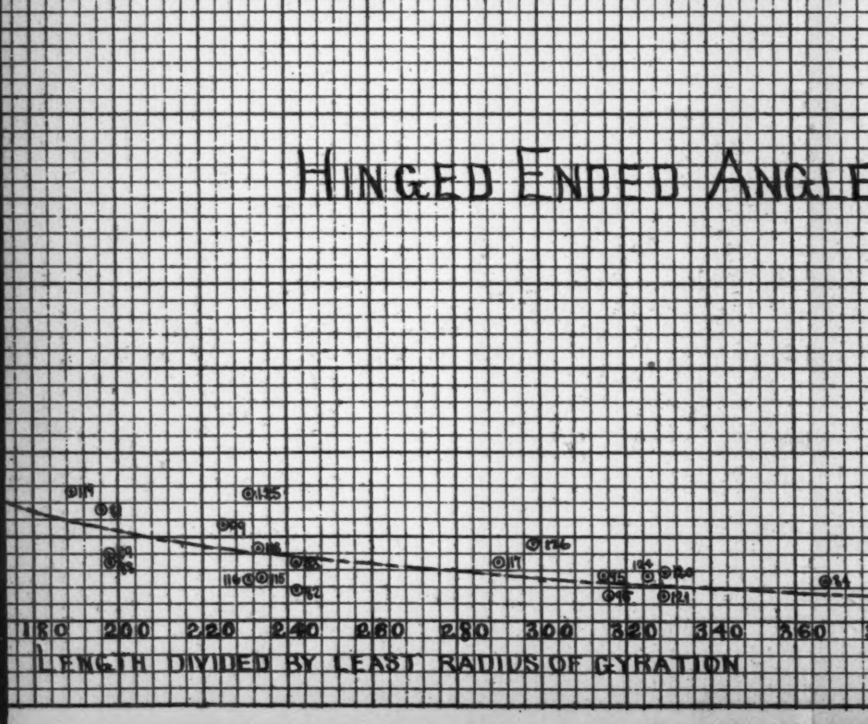
PLATE XXVI
TRANS. AM. SOC. CIV ENG'RS
VOL. XIII NO CCLXXIX
CHRISTIE
ON IRON STRUTS.





Lbs. per Sq. inch
60000
50000
40000
30000
20000
10000
0
20
40
60
80
100
120
140
160
180
LENG
Lbs. per Sq. inch
60000
50000
40000
30000
20000
10000
0
20
40
60
80
100
120
140
160
180
LEN


HINGED ENDED TEES.
⊙ TEES.
⊡ BEAMS
+ CHANNELS
180 200 220 240 260 280 300 320 340 360
LENGTH DIVIDED BY LEAST RADIUS OF GYRATION.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LENGTH DIVIDED BY LEAST RADIUS OF GYRATION

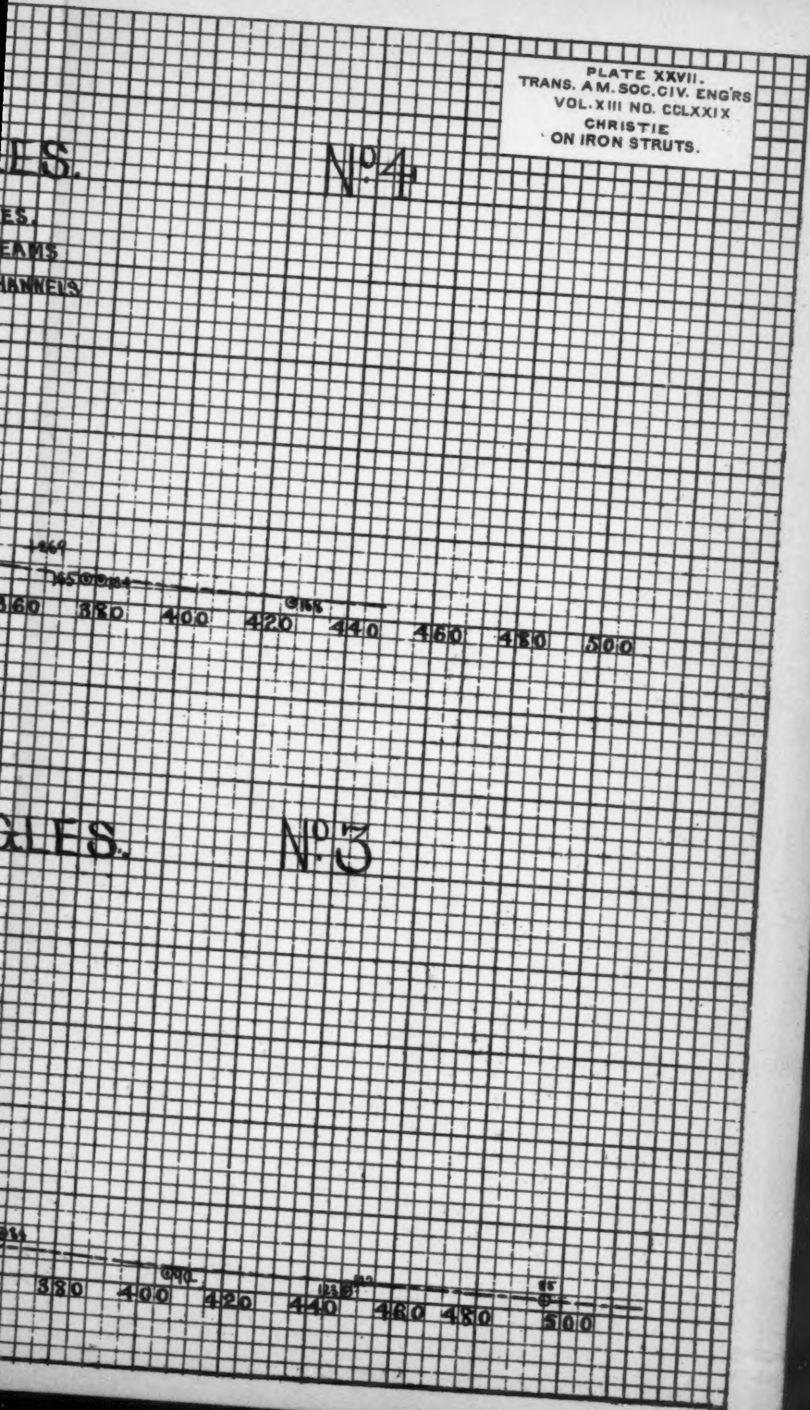
PLATE XXVII.
TRANS. AM. SOC. CIV. ENG'RS
VOL. XIII NO. CCLXXIX
CHRISTIE
ON IRON STRUTS.
ES.
Nº4
ES.
EAMS
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460
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GLES.
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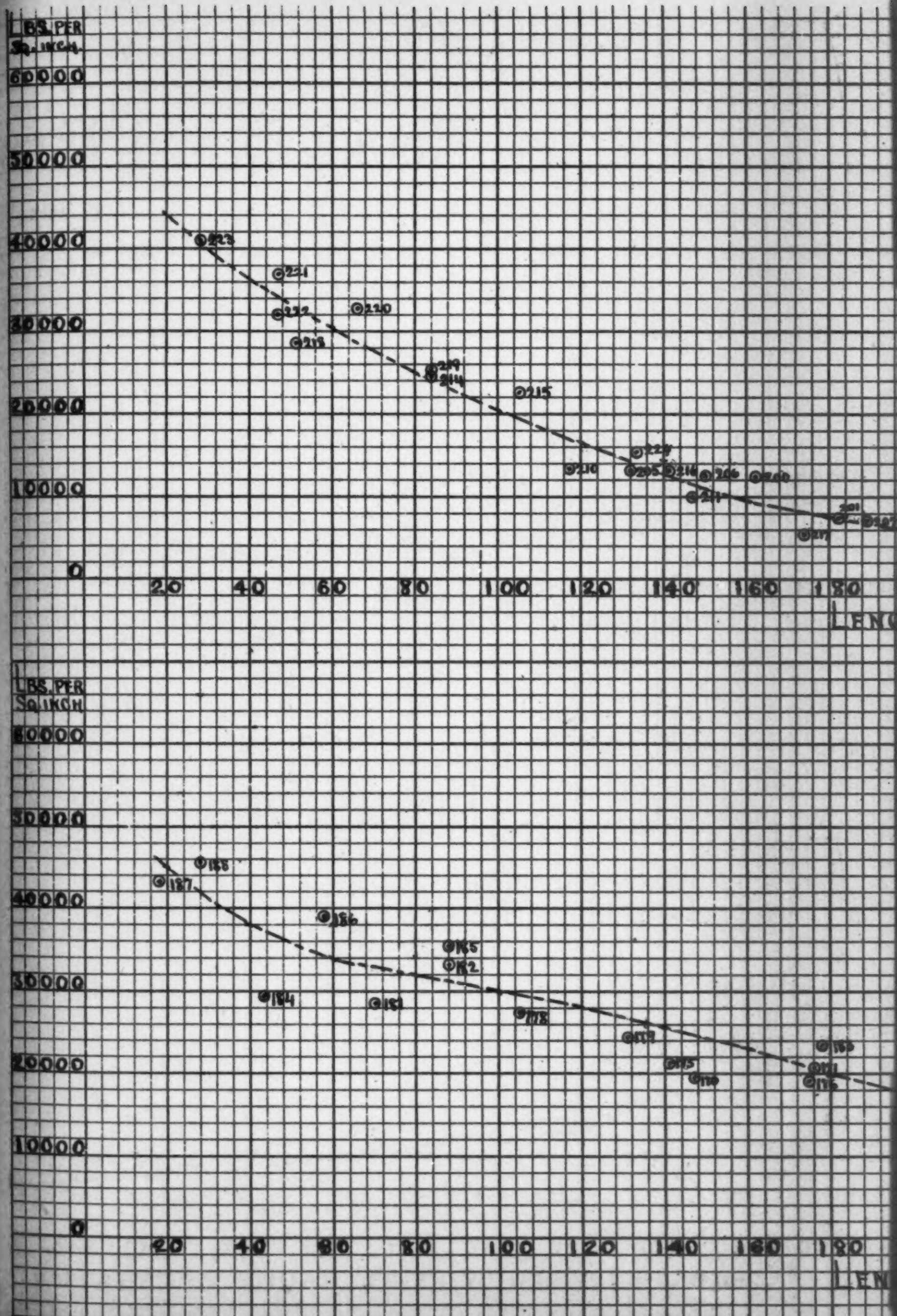

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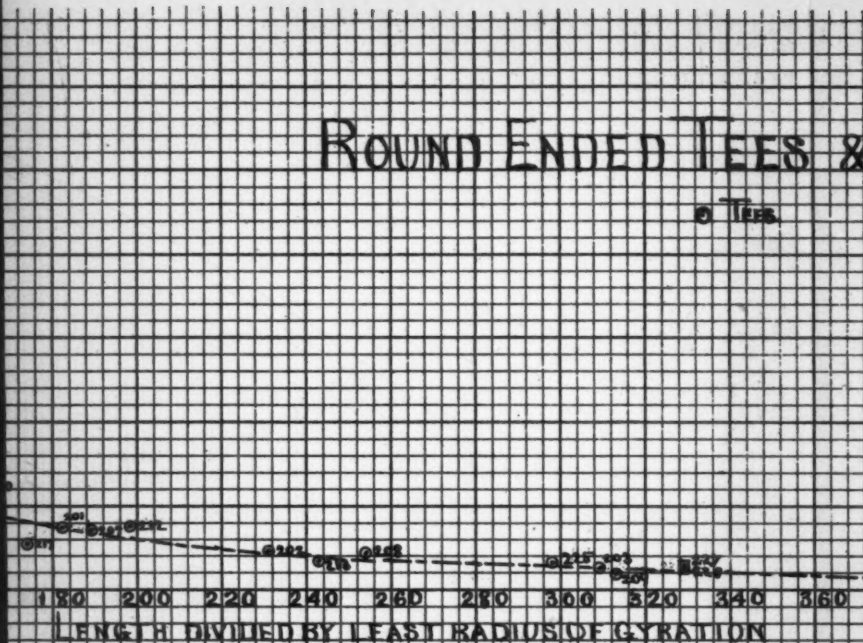
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TEES
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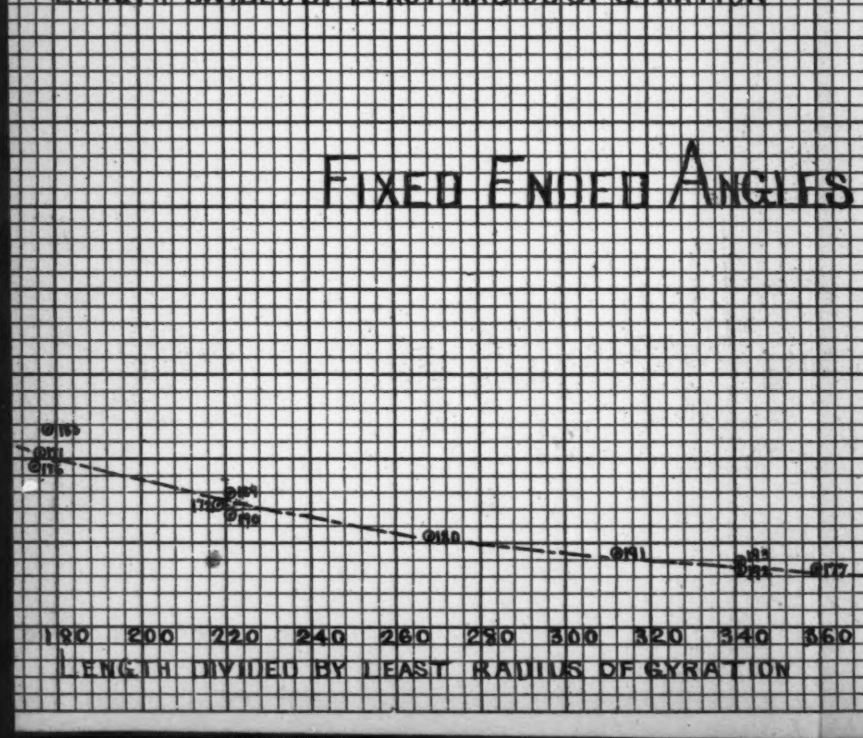
LENGTH DIVIDED BY LEAST RADIUS OF GYRATION


FIXED ENDED ANGLES
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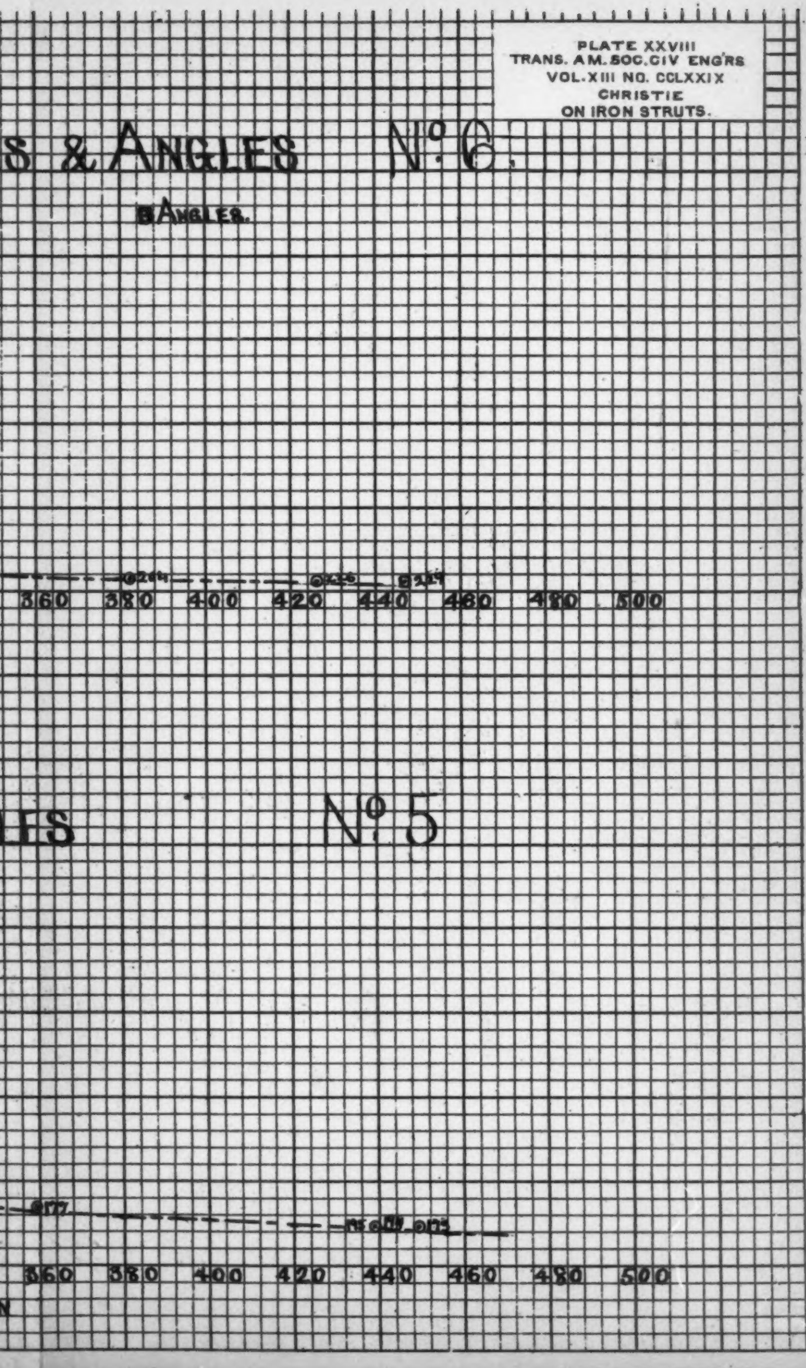
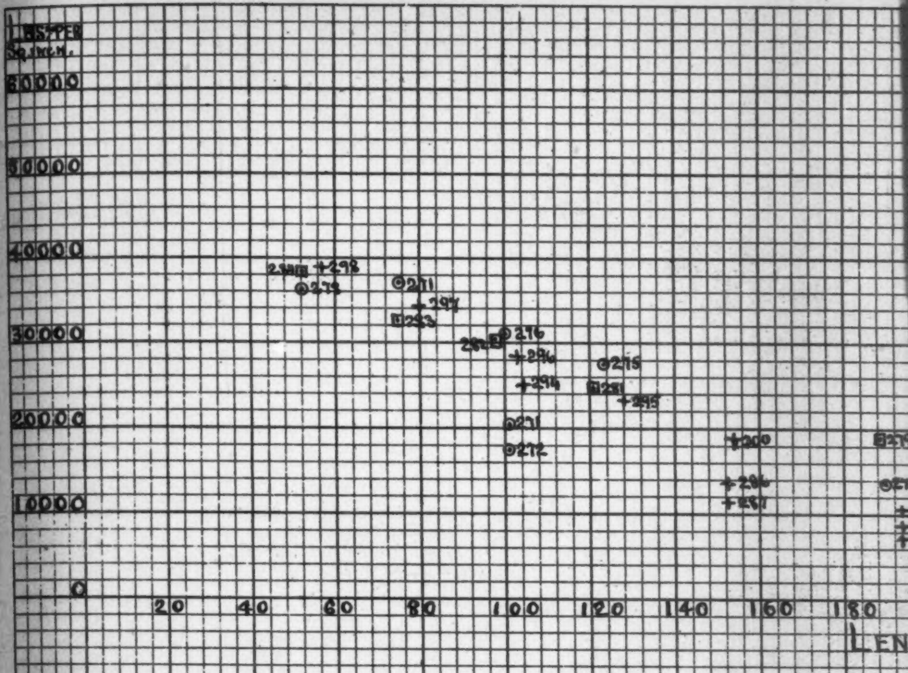
LENGTH DIVIDED BY LEAST RADIUS OF GYRATION

PLATE XXVIII
TRANS. AM. SOC. CIV ENG'RS
VOL. XIII NO. CCLXXIX
CHRISTIE
ON IRON STRUTS.





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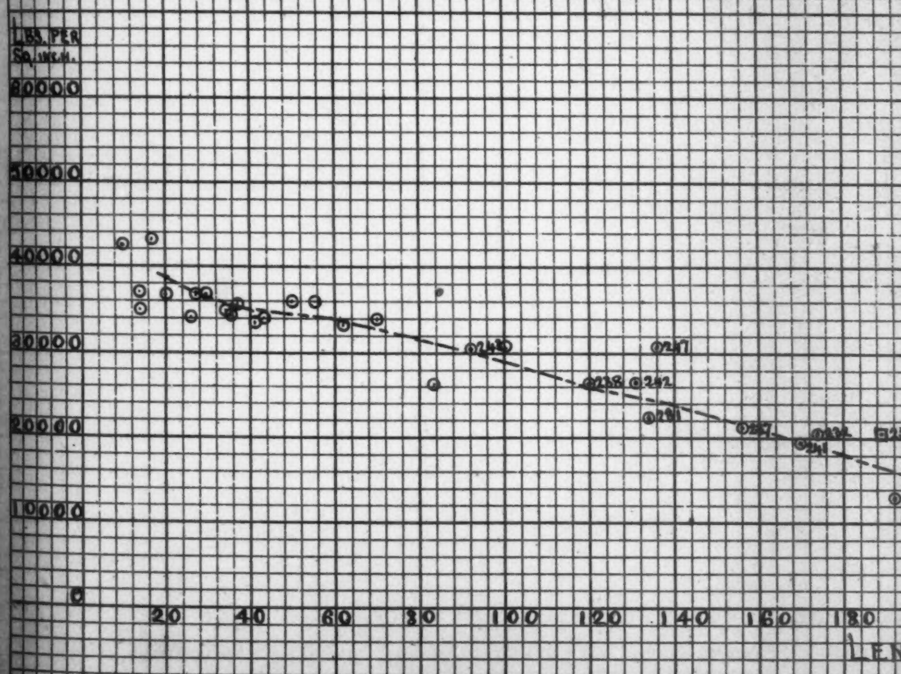

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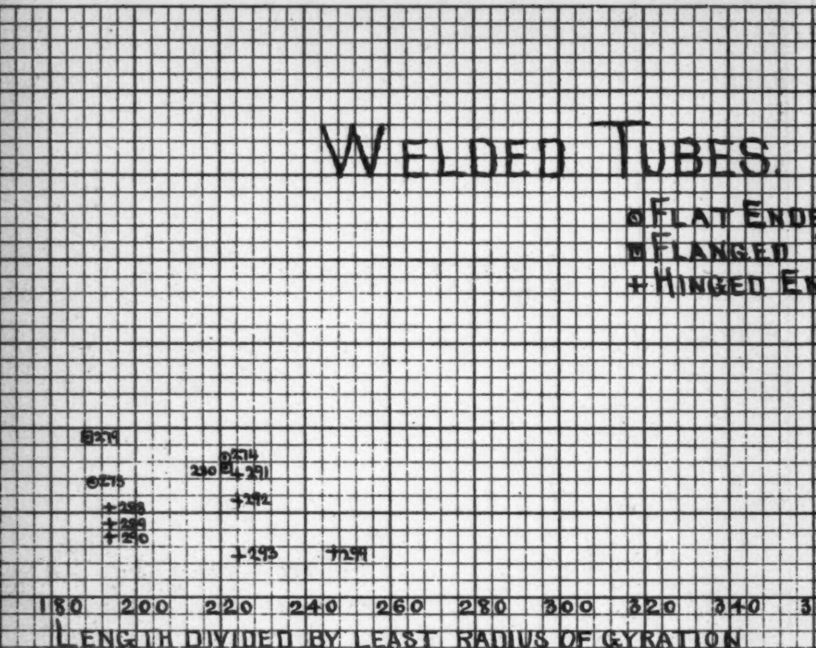
WELDED TUBES.
FLANGED
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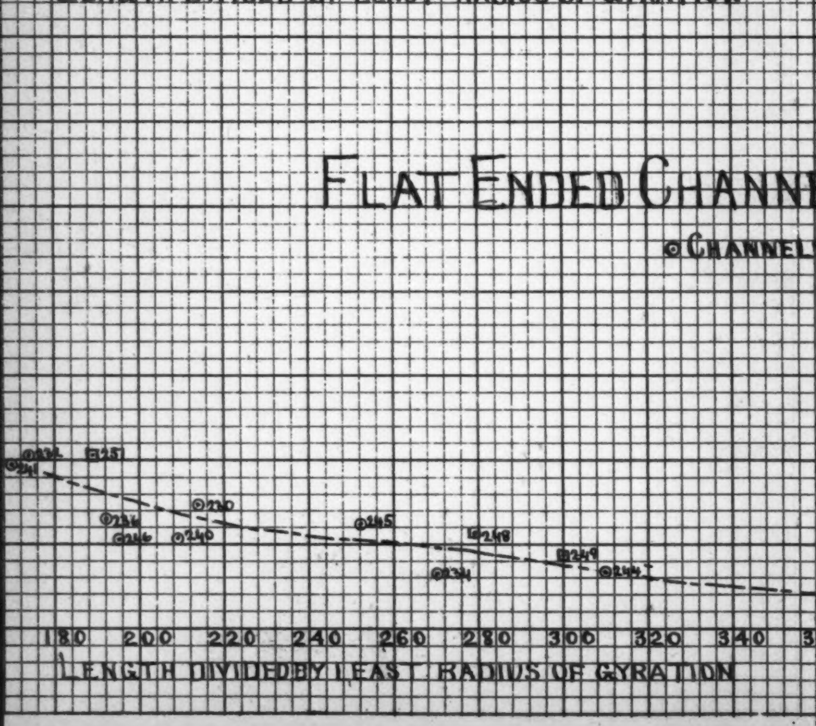
LENGTH DIVIDED BY LEAST RADIUS OF GYRATION


FLAT ENDED
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LENGTH DIVIDED BY LEAST RADIUS OF GYRATION

PLATE XXIX
TRANS. AM. SOC. CIV. ENG'RS
VOL. XIII NO. CCLXXIX
CHRISTIE
ON IRON STRUTS.